INSECT PESTS OF CROPS

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India—The Land And The People

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INTRODUCTION

In ORDER to keep the size of this book within the prescribed limits, only a very small fraction of even the important pest fauna of the country has been dealt with. The main aim has been just to give a sample impression about the pest problems of India and no attempt has been made to present a comprehensive account. Also as the book is primarily meant for a general reader, considerable amount of liberty has been taken as regards some orthodox entomological conventions regarding the names of species and their authors. Instead of trying to conform to the latest name of any particular pest, the author's preference has generally been for the one which has been in use for a pretty long time. Invariably the names of authors of species have not been mentioned. In fact, when long names of authors or more than one author's names were to be appended, they have been purposely left out. Again, no effort has been made to cite references.

As a preamble, it may be stated that although the insects are minute, the problems created by them are, in their vastness, inversely proportional to their size. The insect problems are of such a huge magnitude that in order to understand them in their true perspective, our thought-processes have to work at the highest level of comprehension. The evolutionary maturity of insects as a class is about 500 times that of man. Insects appeared on the scene of existence, according to various estimates, about 250 to 500 million years ago. The extent of antiquity of this origin of insects can be gauged from the fact that the human being has come on that scene only a million years ago. Ever since such an early geological epoch, insects have held their own against all odds and today they constitute the most dominant class of the animal kingdom. The total number of insect species is more than the total number of species of all other forms of life put together. Insects are the only creatures in the whole of the living world, including both animals and plants, which can lead an active aerial existence with such minute size as they generally have.

One of the most important characteristics of insects is that they have six legs; this number is optimum because during their movement on a solid surface, the body always rests on a tripod while the other three legs move forward; this ensures best stability during movement. The life-history of several groups of insects consists of four well-defined stages, viz. the egg, the larva, the pupa, and the adult. Two of these stages, viz. the mainly feeding stage of the larva and the mainly reproductive stage of the adult, are so different not only in structural details but also in their requirements of both food and habitat that the internal competition between the parent and the offspring for both food and shelter gets completely eliminated. Also the same indiviual is able to exploit at least two different kinds of food and habitat. Further, by the interpolation, between the larval and adult stages, of the quiescent stage of pupa with great resistance and practically no requirements of food, the two active stages are best fitted into the different seasons.

Finally, the zeniths of evolution depicted by such social insects as termites, ants and bees are most interesting and instructive. They have evolved their own agriculture, their own dairy, their own division of labour and social order and their own language. All these constitute reliable indices of the structural, developmental, behaviouristic and organizational perfections of the insect world and if we ponder over all these realities, we shall soon realize that man faces a very tough challenge from the insect world.

One of the secrets of this continued and almost explosive success of the insects is that they have been exploiting their very minuteness to keep their enemies lulled into a false sense of complacency and they are playing the same game today with man. Most of usremain quite complacent about insect problems. They are neither so minute as to cause a sort of blind awe as other microscopic organisms do nor do they generally create any spectacular effect like lions, tigers, etc., except under certain specialised circumstances like the ones created by locust invasions. Thus humanity is being, so to say dodged by insects. Hence the pest problems are practically getting out of our control or at least we are getting caught in a very serious vicious circle particularly in the field of agriculture and yet many of us do not adequately realize that the situation is really getting

almost hopeless. Those who do not appreciate this are actually victims of the insects' game of dodging humanity.

The nature of the vicious circle in which we are caught is somewhat like this: The population is rising fast, tightening the grip of hunger on the throat of humanity. The only way of keeping this grip somewhat relaxed is the intensification of agricultural production. At this stage a peculiar law of nature begins to operate. The more ew intensify agriculture, the more does the pest situation go on getting proportionately accentuated. The evolution of insects coincided with the evolution of the land plants; the origin of insect pests coincided with the origin of agriculture and since then every major step in the direction of increasing production has been bringing in its wake a worsening of the pest situation unless equally adequate steps are also taken to arrest pest accentuation. This phenomenon is very spectacularly operating under Indian conditions at the moment. The new strategy of agriculture has been in operation only during the last few years and the result is that even during this short period the country has faced a number of unexpected pest epidemics and these have been dealing blow after blow to our production drive. Now the solution for such a situation is not in slowing down the production drive as some people tend to suggest but in proportionately enhancing protection research.

An analysis of the protection drive shows that as the strengthening of pest control research has not kept pace with the speed of the production drive, the pest upsurges have been taking place in unexpected and unforeseable manner and therefore they have to be tackled as in a state of panic. Now when we have to tackle an unexpected pest epidemic, the only weapon usually found handy is a pesticide which is certainly the best remedy as a first-aid and at least as a temporary palliative. In this way, the use of pestidices has been gatting boosted almost to the exclusion of all other methods of pest control. This lop-sided development in pest control has begun to create very serious problems.

Futher, for the developing countries like India, a one-sided approach to pest problems through pesticides alone does no fit into the national economy. For example, in India the money needed for pesticidal pest control runs into hundreds of crores, i.e. thousands of millions per year. Even if the country makes this huge provision

somehow, it will be extremely difficult to get enough foreign exchange or even enough pesticidal chemicals and the adverse side-effects of such large-scale use of pesticides will certainly go out of our control.

The only remedy, therefore, for such a situation seems to lie in formulating and practising integrated pest control in which all other methods besides pesticidal control will be tried equally seriously. This aspect has been specially kept in view in suggesting control measures in this book.

The book contains thirteen chapters devoted to a rather detailed description of a total of 62 pest species or groups of pest species which are either common to several commodities and crops or specific to certain groups of crops. Also, passing reference has been made to a number of other pests. The idea behind grouping them according to different commodities or crops is that after dealing with the important pest of a particular group, an effort has been made to focus attention on the overall pest problems of that crop as a whole and also make suggestions how a control schedule for the crop can be worked out and improved upon from time to time, by taking into consideration all its important pests.

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CHAPTER I

POLYPHAGOUS PESTS

Crop Pests

There is hardly any crop which is not damaged by one or more insects at different stages of its growth. Based on their feeding habits the pests have been placed in different categories. *Monophagous* are those insects which are known to feed on only a single species of plants. There are very few pests which can be claimed to be monophagous; some of these have been categorised as such because possibly their wild alternate hosts have not been discovered so far. *Oligophagous* are insects which confine their feeding activity to plants of one family, a well known example being cabbage butterfly. The *polyphagous* insects feed on a very large number of cultivated and wild plants. Keeping in view the scope of this book, the general polyphagous pests have been dealt with first.

Pests Common to Several Field Crops

There are many insect pests which by their damage cause appreciable loss to a number of cultivated crops and plants of economic importance. As mentioned above these insects are referred to as polyphagous pests. Some of these have such a diverse and wide host range that it will not be appropriate to deal with them under any specific chapter on pests of different crops. A few important examples of these pests are therefore being discussed under this chapter on polyphagous pests.

LOCUST

(Plate I)

The literal meaning of the word 'locust' is 'plague'. Since times immemorial certain species of short-horned grasshoppers have

acquired the name 'locust' mainly because at certain times they breed in large numbers and form huge congregations and then fly about in swarms of immense magnitude invading and devastating vast areas in distant regions up to hundreds and thousands of miles away from the place of their origin. An idea of the magnitude of the dense masses in which they often fly about can be had from the recorded observation that once a locust swarm got swept by the waves of the ocean along the sea-shore and the carcasses of the locust formed a huge wall forty miles in length and several feet in height along the sea-shore. Also it is on record that once during an attempt to destroy a locust swarm, two thousand four hundred and forty-seven tonnes of these insects were collected.

In all, eleven species or sub-species of grasshoppers have acquired the name 'locust' in different countries of the world. Three of these species occur in India. These are the Desert Locust, the Migratory Locust and the Bombay Locust. The Desert Locust has been causing greatest havoc, particularly in the Indian subcontinent. This species is an international enemy of agriculture which has been causing extensive damage in about seventy different territories right from north-west Africa through all the countries of the Middle East right up to Assam in the east and Kerala in south India. In the north the damage has been reported from Portugal, southern Spain, Turkey and Uzbekistan in the southern region of the Soviet Republic and in the south the damage is known to have occurred up to Tanzania.

The most peculiar phenomenon about the locust is that there has been a definite, though not quite a regular, periodicity in locust activity right from the beginning of the 19th century, i.e. from the time authentic records are available for locust activity in India. There have been periods of locust outbreaks varying up to several years separated by periods of recession of equally varying durations. A total of fifteen such cycles is on record in India since 1812. The outbreak years are: 1812, 1821, 1834, 1843, 1863, 1869, 1878, 1889, 1896-97, 1901-03, 1906-07, 1912-15, 1926-31, 1940-46 and 1948-63.

The causes underlying the periodicity of locust cycles are still shrouded in mystery. However, investigations on the life economy of this insect have revealed that the Desert Locust exists in

two distinct phases, namely, in the *solitary* phase during the periods of recession and in the *gregarious* phase during the periods of outbreak and that it gets transformed from one into the other through what is known as the *transiens* phase. The same species of locust in these three phases behaves and looks so different that in the past the different phases were considered to be different species; even the body-structure differs significantly in different phases. During recession periods between two epidemics, the Desert Locust lives in its solitary phase: it breeds like ordinary grasshoppers and that too it does only in certain desert and semi-desert areas and even in these regions the breeding is scattered in patches. Hence in *solitaria* phase this species does not attract any serious attention. Later on when the conditions are favourable for the locust outbreak to start, there is a definite phase transformation from solitary to gregarious. Breeding becomes concentrated and the progeny of the individuals which were so far living as ordinary grasshoppers develop a tendency for gregarious existence and an urge for long-distance migration. This change in behaviour is also accompained by certain morphological and physiological changes. Also the colour of the body is different in the two phases, both in the younger stages and in the case of adults.

As to why these phase transformation from solitary to gregarious form and locust outbreaks have been occurring in periodic and cyclic manner, i.e. during certain intermittent periods and not in others, the only explanation attempted so far is contained in what is said to be the Biotic Theory of the Periodicity of Locust Cycles propounded by the present author. According to this theory, the periodic locust outbreaks have been following periods of climatic extremes which annihilate the enemies of the locust in desert and semi-desert regions where this species lives in its solitary phase during periods of recession. In these areas the fauna in general leads a life of marginal existence and the climatic extremes seem to reduce substantially the number of the enemies of locusts, particularly the vertebrate predators who are unable to find suitable ecological niches to escape extremes of heat and dryness. This reduction in the number of predators presumably reduces what is known as environmental resistance in the area and leads to population explosion of

the Desert Locust. Essentially the same line of arguments also provides the explanation why the Deset Locust is not able to become endemic outside the semi-desert areas. The ordinary breeding areas of the Desert Locust seem to be delimited by the population density of the enemies of this species. On the periphery of the desert areas the breeding of the Desert Locust seems to decrease as the population of its predators increases till it becomes impossible for the locust to exist due to the pressure of its enemies, i.e. due to increased biotic resistance. Also inside the desert, which is still more inhospitable, locust-breeding itself may become impossible due to extremes of heat and dryness. Hence locust-breeding takes place in more or less transitional areas between the desert and semi-desert regions. This part of the story regarding the life economy of the Desert Locust is still in the form of a theory waiting to be proved or disproved by actual critical observations and experimentations in these transitional regions.

Another important peculiarity of the life economy of the Desert Locust is that it migrates back and forth rather regularly between its summer and spring breeding regions. The summer-breeding regions receive monsoon rains and extend from the south of Sahara, Libya and Egypt in Africa through southern Arabia and Pakistan to north-west India; the spring-breeding regions, on the other hand, receive winter rainfall and extend from the northern belt of Africa and Arabia through Iran up to Baluchistan. As a result of such migration, this species is able to make use of both the summer and winter rainfall belts for its breeding and thus ensures more generations per year than what it could have been able to complete if it were confined to any one of the two regions. In other words, this insect is more independent of one of the climatic factors,. viz, the seasonal nature of the rainfall in either of these breeding regions. This partial independence of one of the many climatic factors resulting in an increased number of generations per year is bound to affect favourably the magnitude of population explosions which occur from time to time in the case of the Desert Locust. Extensive studies have indicated that these regular migrations of the Desert Locust between widely separated seasonal rainfall belts are assisted by the same prevailing winds as cause rainfall in these regions. All the same, certain behaviouristic

peculiarities of the species are bound to be involved in these migrations because the same prevailing winds are not able to cause such large scale population displacements in the case of other grasshoppers allied to the Desert Locust. These peculiarities need to be carefully explored.

The full life history of an individual locust consists of the egg-stage, the hopper stage and the adult stage. The eggs are laid in batches of up to 150 or more, deposited in soil at depths of 8 to 15 cms. The female locust is able to deposit its eggs so deep in the soil by thrusting and extending the hind end of its abdomen which allows much elongation for this purpose. Hence loose sandy soil is suitable for egg-laying. An individual egg looks like a grain of rice which is yellowish in colour, 7 to 8 millimetres in length and about one millimetre in girth. This egg stage lasts, subject to the prevailing temperature, for periods of about 1½ weeks to 4 weeks. At this stage a suitable amount of soil moisture is most essential for the proper development of eggs. If this prerequisite is provided by timely rainfall, the eggs hatch into what are called vermi-form larvae which wriggle their way out of the soil and, after casting off a kind of membranous covering in which they are enveloped, they enter the hopper stage of their life. From this stage onwards the colour, the structure and the behaviour depend on whether the locust is in its *solitary* phase, breeding in a scattered manner and in low population density or in its *gregarious* phase, breeding in a concentrated manner and in high population density. However, the hopper stage lasts for about 3 to 10 weeks depending on the prevailing temperature and during this stage the individuals moult, i.e., cast off their skin several times. After the final moult as a hopper, the individual enters the adult stage and about 10 to 15 days thereafter reproduction starts. In the solitary phase, the hoppers are either green or acquire the colour of the vegetation they are in; they behave like ordinary grasshoppers and remain scattered and as adults they stay grey and fly mainly during the night and as individuals. In the gregarious phase, on the other hand, the hoppers exhibit a black colour pattern and march for long distances in definitive bands. When adults, they are pink while immature and yellow in the sexually mature stage; they fly in swarms during day.

CONTROL

Man's strategy to fight the locust menace has to consist of four steps described below:

(*a*) *Locust Intelligence and Warning, and Co-operative Measures against Locust Invasions*

One of the peculiarities of the life economy of the Desert Locust is that it breeds in scattered and ordinarily inaccessible pockets in desert and semi-desert areas. Hence, unless there is an adequate intelligence organization, it is not possible to detect in time the signs of population explosion and the consequent locust invasion. This basic need was realized only about forty years ago when a permanent Locust Warning Organization was set up in India in 1939. The main function of this Organization is to keep a constant vigil, by means of effective surveys and study, on the population fluctuations and tendencies of phase transformation all over the possible breeding regions of this insect and to issue periodic warnings to all concerned. Further, the breeding belt of the Desert Locust extends across international boundaries of many countries right from the middle of India to the western parts of Africa. Also, locust swarms are capable of invading areas thousands of miles from the place of their origin. Hence isolated efforts of any one country cannot provide effective insurance against locust invasion. In view of these considerations there has been very active international collaboration in the field of locust research and control. There has been for many decades the International Locust Research Centre in London which has been arranging international conferences on locust control. Trained Indian teams have been deputed from time to time to Iran, Arabia and other countries to carry out locust control. The United Nations Special Desert Locust Project was initiated by FAO in 1960. In fact, the field of anti-locust activities is one of the earliest and most encouraging examples of interational co-operation and collaboration. All the same, these activities have to be on a much bigger scale than what has been possible so far. Even in the case of a single country like India it was at one time found necessary to evolve a co-operative scheme in which the

expenditure on anti-locust operations in the locust-breeding belts had to be suitably distributed among various States according to their vulnerability to locust invasions. Later on these expenses began to be met from the Central budget.

(*b*) *Prevention of Swarm Formation within the Breeding Belts*

Prevention, if practicable, is always better than cure. Hence the most rational approach to the solution of the locust problem is to adopt measures as would not allow the locust population to assume such proportions as would lead to swarm formation and migration from the breeding belt. The scientific know-how for doing so is now available but there are immense practical difficulties mainly due to the magnitude of the problem, and on account of the vastness and inaccessibility of the breeding areas. The methods which have been tried out successfully for killing locust population in its breeding ground are as follows:

(*i*) *Measures Applied at Egg-Stage :* In the past eggs had to be destroyed merely by mechanical means like digging out, ploughing or flooding the egg-infested land, etc. But now there are persistent chemicals like aldrin and dieldrin which, if sprayed or dusted on the egg-infested fields, will stay there to kill the locust hoppers as soon as they hatch out. Even complete coverage of the whole area is not necessary and strip application has been resorted to for the job because hoppers move about in bands across these treated strips and get poisoned.

(*ii*) *Measures Applied at Hopper Stage :* Mechanical destruction of locust hoppers has been found to be quite feasible in the past. Concentrated breeding and tendency of hoppers to march in definitive bands greatly contribute to the success of such mechanical means of destruction as burning the whole congregation of hoppers with flame-throwers, driving the marching bands of hoppers into trenches made specially for burying them alive. Later on a comparatively less laborious method of poison-baiting was evolved. It was found that locust hoppers readily accepted as food different kinds of material such as wheat bran moistened with enough water to make it crumby. Advantage was taken of this fact for mixing a number of stomach poisons like sodium arsenate and sodium fluo-

silicate in such food baits scattered amongst or in front of marching bands of hoppers. In recent years rapid advances have been made in evolving a large variety of highly toxic insecticides which kill the hoppers by mere contact and these can be directly dusted or sprayed with great speed either by means of ground machines or by means of aeroplanes. A number of these chemicals can be used for poison baiting as well.

(*iii*) *Measures against Adult Locusts:* The destruction of the locust becomes far more difficult at the adult stage both because of increased mobility and their much increased hardiness and resistance to the action of insecticides. However, the congregations of adults can also be dusted or sprayed with insecticides particularly during night and early hours of the morning or during winter days when mobility is much less. Under such conditions they can also be destroyed by such other measures as large-scale burning by flame-throwers, mechanical killing, etc. depending on the local situation.

(*iv*) *Possible Ecological Control:* Reference has been made earlier to the new biotic theory of the periodicity of locust cycles. The main practical utility of this theory is that it makes it possible to visualize how the locust-cycle can be nipped in the bud by creating suitable ecological niches in the locust-breeding areas so that locust enemies can escape annihilation due to adverse weather conditions and continue to keep down the locust population. Alternatively, it is also envisaged that the rehabilitation of the locust enemies can be expedited by transferring them from the periphery to the locust-breeding areas. It is likely that as a result of this theory the vast locust-breeding areas of India and the world may be reclaimed so as to make them unfit for locust-breeding and thus the problem of locust invasion may get considerably reduced.

(*c*) *Annihilation of Locust Swarms and their Progeny in Areas Invaded by them*

The methods advocated for this purpose are practically the same as those given in the foregoing paragraphs.

(*d*) *Immediate Protection of the Crop from Locust Damage on an Emergency Basis*

A few years ago it was discovered at the Indian Agricultural Research Institute that the kernel of the seed of *Azadirachta indica*, which is a popular local tree called *neem*, can be used as a very effective anti-feeding material against the Desert Locust. If a 0.1% suspension of the kernel of the seed of this plant is sprayed on any crop, that crop remains safe against locust damage for about three weeks. This discovery has put a very potent weapon in the hands of the individual cultivators who used to feel helpless when locust swarms invaded their area. Now with the help of this anti-feeding material, they can ensure the safety of their crops while the pest control organisations are trying to annihilate the swarm by means of insecticides applied from the air or by ground squads.

WHITE ANT

(*Termite*)

(*Plate II*)

Termites or white ants, as they are commonly called, are of great interest from various angles. From the economic viewpoint they are responsible for colossal damage to wood in all its various forms—wooden building structure; wooden furniture, all articles containing cellulose, like paper; even decaying matter like cowdung, living plants like forest trees and agricultural crops, etc. To the sociologist the termites offer an interesting field of study in their highly organized social set-up and to the students of evolution they afford a rare example of a peculiar group of organisms which are very primitive in their morphological make-up but highly evolved in their physiological and sociological specialization. The result is that the common name 'white ants' for termites is as correct and appropriate from sociological considerations as it is wrong on the basis of morphological homology. Although the evolutionary distance between white ants and true ants is very large indeed, the mode of living of these two distant groups of insects is very much alike, even though there are certain striking differences in details. Also in size and general appearance, the termites and ants are not very dissimilar; the epithet 'white' is also quite well founded because majority of the individuals of most of the species have a pale-coloured body.

However, the most important and easily distinguishable characteristic of white ants as distinct from true ants is the absence of the constricted waist in the region of the junction between the thorax and abdomen which is so universal and prominent in true ants.

White ants live in colonies located either underground or in what are known as termite mounds or within dead-wood in which galleries and chambers are excavated. As some termites feed mainly on wood, the excavation in the wood serves the double purpose, first of providing food and then of providing shelter for the colony. This sort of cryptobiotic life of the termites has made them thoroughly unfit to face the direct sun or even open air except during the cool and humid hours of the night when they make additions to their mound or make fresh earthen galleries in which they move up and down during the day. The earthen galleries meant to avoid exposure extend for long distances on the surface of earth, buildings and trees. Compared with the imperfections of the tree avenues along the roads made by man, the luxury of constructing fresh covered passages wherever the termites have to extend their activity is practically unparalleled. The royalties in certain lands like the Nawabs in India did seem to have made some move in a similar direction as indicated by the existence of labyrinths and long distance underground connections between different forts. However, modern developments in air-conditioned transport have diverted man's approach to an essentially similar aim in an altogether different direction.

The organization of the termite colonies in general is based on such a rigid system of division of labour as has made an indelible mark on the very body build-up of the different functionaries. These different functionaries constitute well-defined castes like the soldier caste, the worker caste, the reproductive caste and the royalty. In a colony the royalty exclusively retains to itself the sole function of reproduction. Hence they also constitute the reproductive caste and the queen is the mother of the whole colony. Also the royalty is mostly the founder of the colony although succession is not ruled out in an established colony. The individuals of the reproductive caste do not begin their productive function till a couple founds a new colony or succeeds the royalty of its own colony.

The queen is the largest individual the size of which at times

exceeds five centimetres in length and one centimetre in thickness. This highly exaggerated dimension of the queen as compared to the rest of the white ants is mainly due to the enlargement of the abdomen which is full of eggs. This enlargement is only a corollary of the specialized function of the queen which acts as an extremely efficient reproductive machine, laying in some species more than thirty thousand eggs per day. The rest of the colony consists of the king, the functional consort of the queen, three sub-castes of fertile reproductives and two sterile castes of workers and soldiers.

In an established colony the fertile reproductives are like the prince and the princess who have no particular function to perform except to be ready to become subsequently kings and queens of new colonies to be founded by them or to succeed the existing royal couple of the colony itself. There are generally three types of reproductives: (*a*) the *macropterous* ones which have fully developed membranous wings, comparatively larger brains and eyes and the full compliment of normal reproductive organs, (*b*) *brachypterous* ones with rudimentary wing pads, and (*c*) *apterous* ones with no trace of wings at all. Among the sterile castes the workers, who constitute the main labour force of the colony, have undergone reduction in brain and eye development. Their mouth-parts, which are used as the working tools for all types of odd jobs, are fairly strong although much less developed than in the soldier caste. The mouth-parts of the soldier caste are used for very active defence and offence, for giving a tough fight to the enemy; hence they show extraordinary development and strength. Particularly the mandibles are very large, projecting and shaped for a variety of uses. In some species of termites, there is a special rostrum projecting out from the head region and an offensive secretion from a special gland is ejected out from the top of the rostrum; this represents the evolution of chemical warfare even in such structurally primitive insects; soldiers possessing this organ are called Nasute soldiers.

Unlike the true ants in which the workers and soldiers are sterile females, these castes in the white ants contain sterile individuals of both the sexes.

There is an interesting aspect from the sociological viewpoint, particularly under Indian conditions. In India the caste system has been in vogue for quite a long time and it is the general experience

that some characteristics of physiognomy and general body build-up can be roughly associated with different castes. If one judges from this standard one can appreciate much more how deep-rooted the caste differentiation has gone in the case of white ants. Another point of great scientific interest is that among Indians it is easier to expect some sort of association between particular physiognomical characters and a particular caste because there has been to a certain extent what can be called reproductive isolation between different castes. But in white ants the different castes showing such bizarre variation are all the progeny of a single mother. In fact, the mechanism of such prominent caste differentiation in the progeny of a single mother still continues to be an enigma to science although there do exist in the field a few theories offering some tentative explanations.

The propagation of termite colonies takes place, generally during the rainy season when at certain optimum moments, say a clean evening after rains, the macropterous reproductive forms swarm out from the termite nests in very large numbers. Most of this swarm meets destruction at the hands of various predatory fauna like frogs, lizards, etc. All the same, some couples survive, copulate, shed their wings and start founding a new colony. The couple digs a small nuptial chamber for itself and begins to reproduce. To start with the couple takes all the care of tending and feeding the young ones but once a sufficient number of workers are thus reared up they relieve the founder couple of all kinds of labour and begin in turn to tend their parents as royal dignitaries. Thence onwards the abdomen of the queen begins to enlarge till the queen is converted into an egg-laying machine.

The feeding habits of termites are varied and interesting. Some species have developed a peculiar kind of agriculture. They grow and maintain almost pure crops of certain varieties of fungus which they have adopted for their agriculture, just as wheat and rice have been adopted by man. The fungus crops are grown on a type of spongy comb-like structure specially made by the termite workers from comminuted vegetable material which provides a fertile bed for the fungus to grow on. These strange structures, called fungus gardens, are kept in special chambers scattered within the other living chambers and galleries. Other species which feed

mainly on cellulose material harbour in their intestines certain unicellular organisms which are particularly helpful in cellulose digestion. Still others have developed a system of feeding on material which has already been semi-digested by other members of the same colony.

Various species of termites have also developed different kinds of social relationships with other groups of insects and other arthropods. The fauna generally associated with termite nests is known by the common term of *termitophiles*. It includes some which are considered as true guests to the colony, and others which are just tolerated. Also in some cases more than one species of termites are known to be living together in some kind of social symbiosis.

A perusal of the foregoing account of the various fascinating aspects of termite life will show that it is no wonder that man has been finding it extremely difficult to control the damage caused by white ants. Their cryptobiotic mode of life has made it very difficult to study their actual habits and weak points which could have been exploited for their control. A vast amount of wood-testing is going on in various laboratories of the world to determine which wood is comparatively safe from the viewpoint of termite damage and how wood can be rendered termite-proof. Also various structural designs are being tried and suggsted to make a building termite-proof. Some methods have been suggested for exterminating the colonies of mound-building species simply because their termitaria can be easily spotted out. All the same, a large variety of termite species have their nests several feet deep below ground surface. It is the workers from these nests which come up and forage for long distances, destroying valuable crops like wheat, sugarcane, etc. In the past, the only protection against them was to irrigate the fields, preferably with water surcharged with crude oil emulsion which acts as an effective repellent for about two weeks. During recent years, however, a number of persistent insecticides like aldrin and heptachlor have been discovered which can be mixed with the soil and which continue to poison the white ants as and when they come up to forage in the fields so treated. The difficulty, however, is that fresh batches of termites continue to come up from a large number of nests where the termite queen of

a single nest may be laying up to 30,000 eggs per day. Thus repeated treatments may be necessary in heavily infested areas.

HAIRY CATERPILLAR

(Plate III)

There are many species of hairy caterpillars in India. They are the young ones of generally moderate-sized moths which have often conspicuous colouration. The real utility of their bright colours is not well understood because majority of them are of nocturnal habit. It is, however, surmised that the bright white background of the wings might be conferring some sort of warning prominence to these insects particularly during dusk. In other words, these moths may be distasteful or even harmful to the predators which might be trying to catch and devour moths in general. Hence, it might be useful for these moths to be prominently marked so that the predators may get timely warning that it is harmful or at least useless to try to catch them. But for this prominent warning colouration, as it is technically called, these moths would have often become victims of the predators' exploratory catch even though the predators would not have actually eaten their dead bodies. This interesting phenomenon of ensuring safety by means of warning colouration is fairly common in the world of insects and also some other animals. Another quite common characteristic of the group is that the moths appear in large numbers during certain fixed seasons when climatic conditions are best suited to them. They lay eggs generally in prominent clusters on the leaves of both cultivated and wild plants and caterpillars hatching therefrom are polyphagous to various degrees. They are characteristically long, covered all over with prominent hairs and conspicuously coloured. When the caterpillars pupate, they use their hair for preparing the cocoon.

Among the whole group of hairy caterpillars, the so-called red hairy caterpillar (*kutra*) is the most injurious to agriculture throughout India. Although those found in the northern and southern regions of the country are said to belong to two species of the genus *Amsacta*, their habits, nature of damage, etc. are so similar that separate descriptions are not called for. As the name indicates, the caterpillars are covered with hair and are reddish-orange or

brownish-orange in colour. The full-grown larvae measure up to more than six centimetres.

The parent moths of the red hairy caterpillars appear in large numbers after the first few good showers of the monsoon when they are often attracted to light and can be easily distinguished by their comparatively heavy body and prominent white wings with a somewhat reddish fringe and a few blackish dots. They lay eggs in large prominent batches mainly on the leaves of both wild and cultivated plants. These egg masses look like clusters of poppy seeds specially conspicuous against the green foliar background. The larvae hatch out within four to five days after the eggs are laid and immediately begin to feed. They remain congregated for a few days and then disperse. Their feeding propensity increases with age and as the vegetation at this time of the year is not very profuse they soon practically finish the vegetation in the fields where the egg-laying originally took place and thereafter they march out in large bands to neighbouring fields and continue to migrate from field to field after almost completely browsing the area they visit. In years of severe outbreaks, field after field may have to be resown in the beginning of the season and later on it becomes too late even for resowing. In less severe years the damage is not very spectacular in the beginning and often the cultivators wake up to the calamity rather too late when the control of the pest becomes very difficult. This kind of feeding actually continues up to about September when the full-grown caterpillars begin to go down into the soil to pupate. When control measures get delayed up to this part of the season, at times the cultivators are likely to get duped into the feeling that the measures adopted in their fields have been very successful, while the spectacular disappearance of the pest may be mainly due to the larvae having gone down into the soil for pupation. However, before pupation a large number of the larvae migrate from the cultivated fields to the neighbouring uncultivated area. Here they pupate in the soil and remain there till the onset of the monsoon the following year. In other words, they remain underground for the whole of winter and summer and they emerge as moths again after the first few good showers of rain of the following year's monsoon.

There are two very instructive points of general biological interest associated with this portion of the life-history of this and a few

allied species. Firstly, the tendency to migrate for pupation from the cultivated fields to the uncultivated area, wherever it is possible, has been obviously acquired through evolutionary processes for ensuring better survival of the species. In this way, the pupae are saved from the disturbance and mortality due to cultural operations carried out in the cultivated fields during the whole of the winter and summer months. It is quite easy to visualize the evolution of this tendency. All the individuals which pupate within the cultivated fields might have been largely getting eliminated due to mortality brought about by cultural practices while those migrating to safer niches might have been having better chances of survival. The next interesting point referred to above is that this type of life-history provides an excellent example to illustrate how some species of insects make use of their pupal stage, which has no food requirement of its own, for nicely fitting their two active stages—one, the mainly feeding stage (the larva) and the other, mainly reproductive stage (the adult)—into the two portions of the year most ideally suited for these two stages and separated by a long period of time extending over the whole of winter and summer. In fact, the pupal period lengthens or shortens according to the late or early arrival of the monsoon.

Control Campaign

The red hairy caterpillar and the related species are most difficult pests to control by means of conventional insecticidal treatments, particularly if the control measure is delayed till the larvae reach the advanced and full-grown stage at which their damage becomes more spectacular and when they generally attract serious attention. A large-scale campaign approach at co-operative or government level is inevitable in the case of this pest because its grown-up larvae migrate in millions from field to field after practically browsing them like cattle, one by one.

During recent years, several entomologists have been trying to find out more and more toxic chemicals for killing the grown-up stages of the *Kutra* caterpillar because at this stage the farmers become very anxious to control the havoc and also the mortality of such large-sized insects in appreciable numbers creates a very spectacular effect. This approach is not only being found to be quite difficult but it is

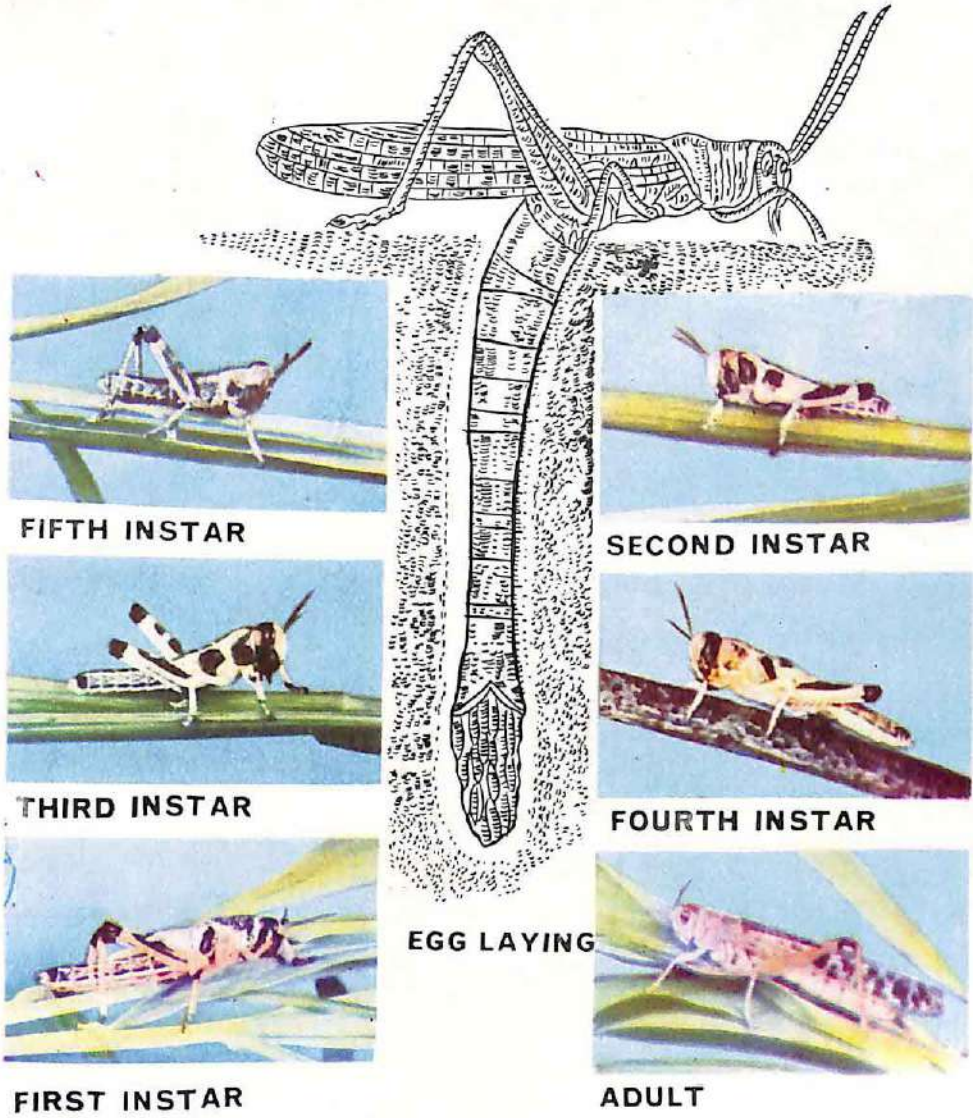

Plate I—DESERT LOCUST

The central figure in black and white represents the desert locust laying eggs deep in the soil by stretching and extending its abdomen to the maximum extent; this is a diagramatic sketch. The other six coloured illustrations respresenting various instars of the desert locust have been taken from the publication entitled *Hungry Thief* issued by the Shell Petroleum Co. Limited (1956).

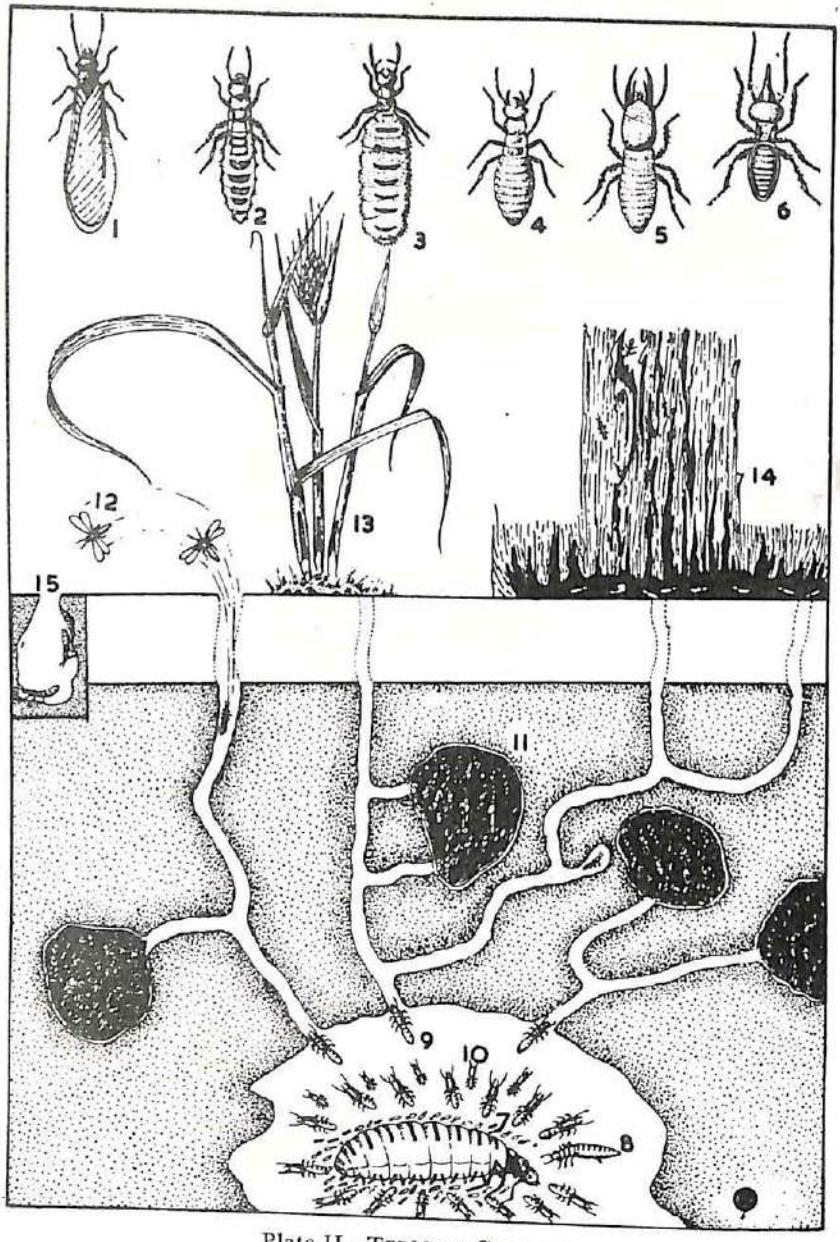

Plate II—TERMITE COLONY

1. Winged adult 2. Wingless individual destined to be king 3. Wingless individual destined to be queen 4. Worker 5. Ordinary soldier 6. Nasute soldier 7. Termite queen in underground nest. 8. Termite king 9. Termite soldier 13. Termite worker 11. Fungus garden 12. Winged adults coming out of underground nests 13. Termites attacking wheat plants 14. Termites attacking wood 15. Termite couple starting a new colony.

(Drawn from various sources)

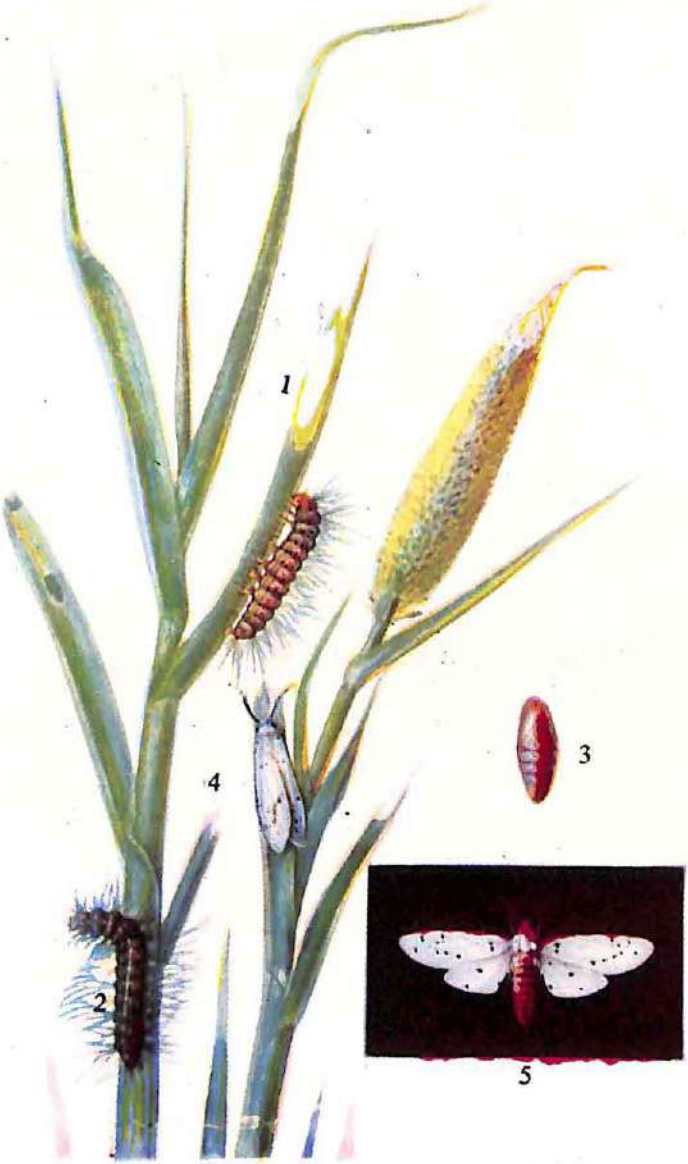

Plate III—Red Hairy Caterpillar

1 & 2. Larvae 3. Pupa 4 & 5. Moths.

(*Some South Indian Insects*, Plate XVII)

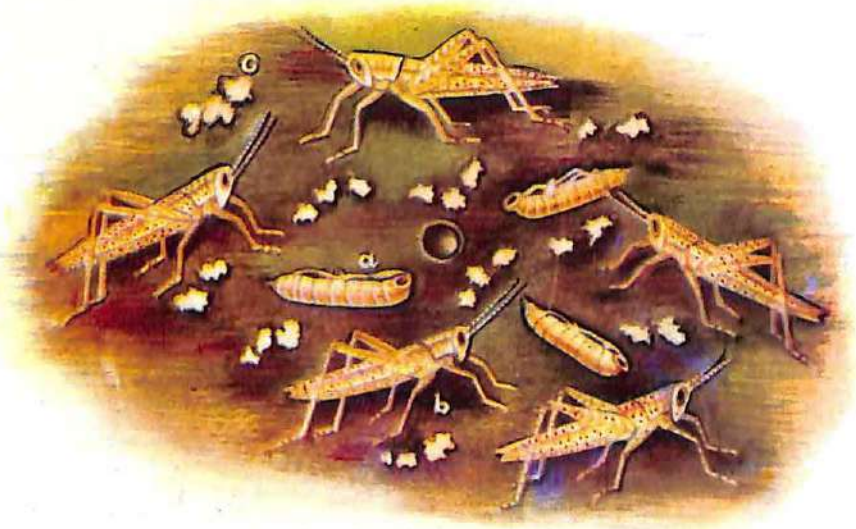

Plate IV—'PHADKA' GRASSHOPPER

(A) Egg-pods entangled in the roots of grasses.

(B) Vermiform larvae, cast off exuviae and young nymphs round the emergence hole.

[After S. Paradhan and K. M. Peswani—I.C.A.R. Bulletin on *Phadka Grasshopper and its Control*]

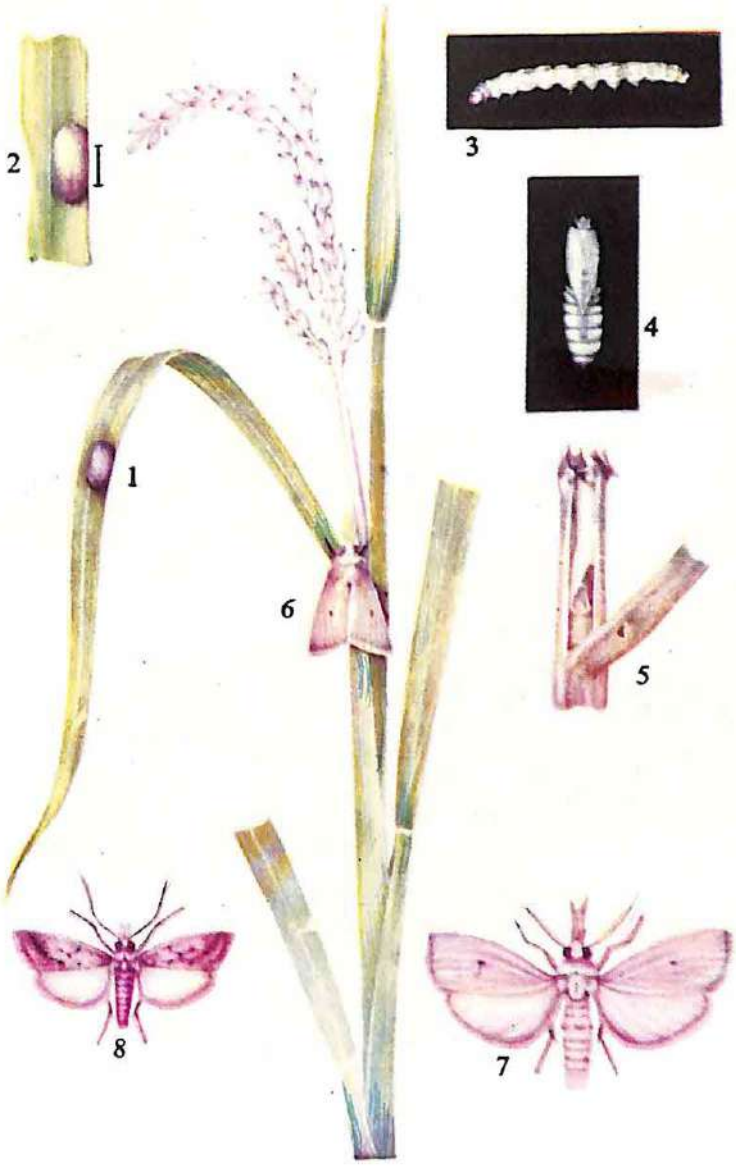

Plate V—PADDY STEM-BORER

1 & 2. Egg cluster 3. Caterpillar 4. Pupa 5. Cocoon in stem 6 & 7. Female moth 8. Male moth.

(*Proc. 3rd Ent. Meeting*, p. 383)

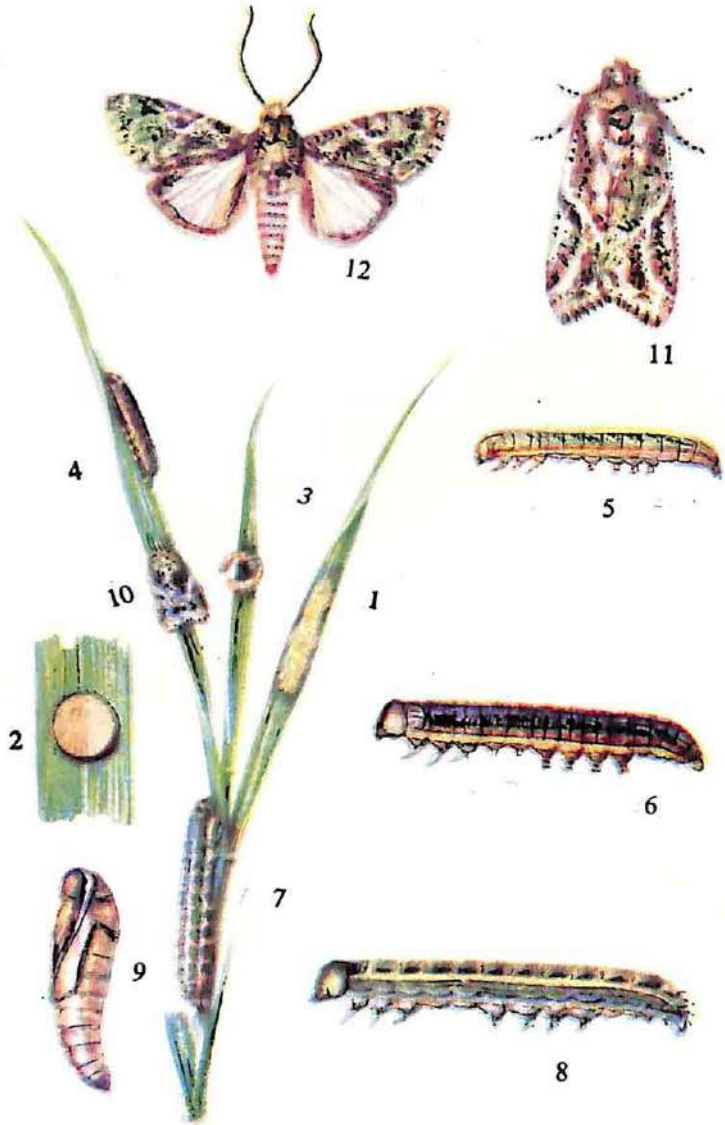

Plate VI—SWARMING CATERPILLAR

1. Egg-mass as laid on paddy-leaf 2. Single egg, magnified 3. Young larva in characteristic attitude 4—8. Larvae in various stages of growth 9. Pupa 10—12. Moths.

(*Some South Indian Insects*, p. 378)

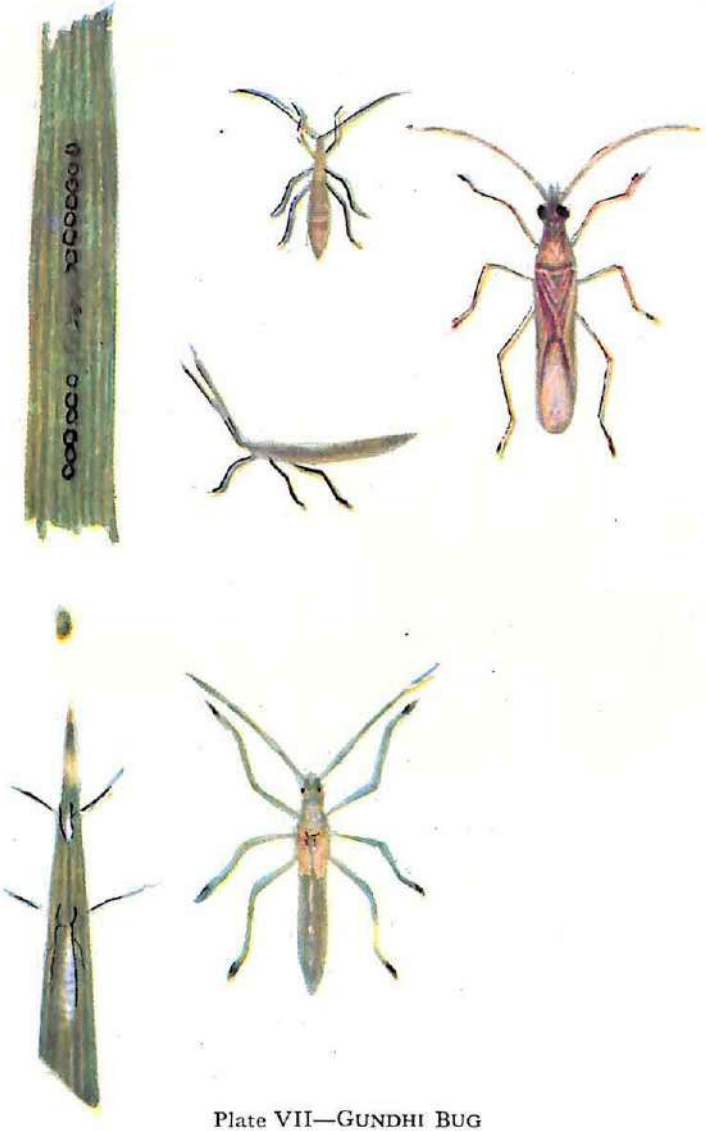

Plate VII—GUNDHI BUG

The figure on the right (*top*) represent the adult bug, those in the middle column show the various nymphal stages, the one on left (*top*) shows the eggs laid on paddy-leaf and that on left (*bottom*) represents the nymphs on paddy-leaf.

(*Mem. Deptt. Agri.*, Vol. 2, p. 1)

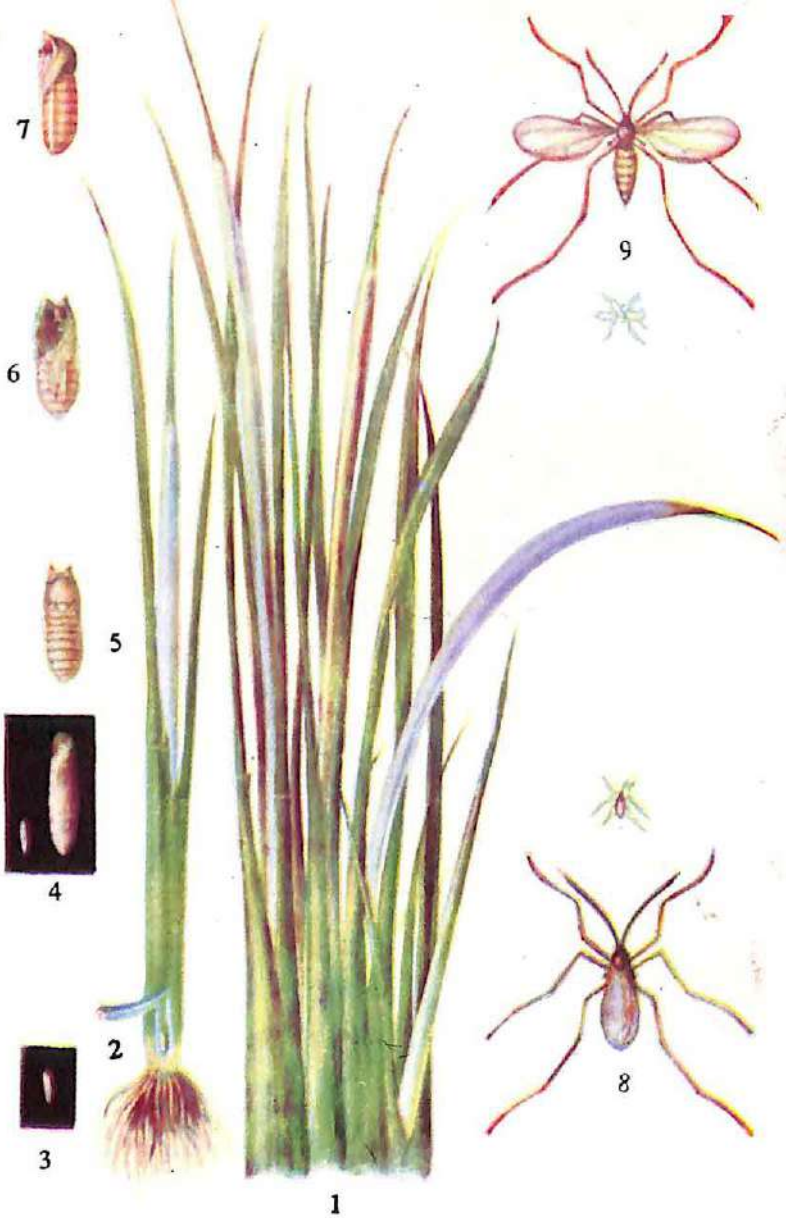

Plate VIII—PADDY GALLFLY

1. Cluster of rice plants several of which are affected 2. Affected plant with the pupa in its natural position 3. Egg (enlarged) 4. Full-grown maggot 5—7, Different views of pupa 8 & 9. Adult fly in sitting and flying attitudes.

(*Proc. 3rd Ent. Meeting*, p. 371)

also not very rational because by the time the infestation reaches this advanced stage, the pest has already inflicted much damage to the crop. The strategy which is most likely to ensure the safety of crops from *Kutra* damage is to organize a timely large-scale campaign on the following lines:

(*a*) The pest spends the whole of winter right from September-October and also early summer in the pupal stage in the soil upto a depth of about half a metre. They emerge from the soil during the monsoon in several successive waves, the first of which comes up soon after the onset of the rains. These adults are attracted to light. Therefore, light traps should be set up as soon as the rains start. The light traps will serve a double purpose: firstly, they will kill quite a large number of *Kutra* moths before they are able to lay eggs and, secondly, they will provide a warning about moth emergence from the soil and thus help in properly timing other control operations mentioned below. Light traps have been recommended for a very long time but they have never been used as a definite item of a well-organised multi-pronged campaign. At first thought, it may appear to be a very primitive recommendation; but serious analysis of the various alternatives, keeping in view the peculiar life-economy of the *Kutra* pest, will convince anybody that a light trap is bound to be a very effective item of the *Kutra* campaign. Hence, in areas where *Kutra* trouble appears year after year, the light trap should constitute the normal piece of equipment which the farmers should keep like a plough, a seed-drill, etc. Alternatively, light traps should form an important item of plant protection equipment like dusters, sprayers, etc. maintained at suitable plant protection centres.

(*b*) The egg masses of this pest are quite large in size and very prominent against the green background of the foliage on which they are laid. Hence, under Indian conditions the collection of egg masses as a regular item of the *Kutra* campaign constitutes a very practical method of effectively controlling this pest. There can be no two opinions about the efficacy of this method from the entomological viewpoint. The success of the method will, however, depend on organizational efficiency. Batches of school children can easily be trained for this purpose. Payment can be made on the basis of the egg masses collected. As the incubation period is about

four days the campagin of egg-mass collection should be so organized that the whole area allotted is cleared within four days. This can be continued as long as egg-laying continues. It is quite obvious that if this single item of the *Kutra* campaign is properly attended to, no other item of the campaign may be needed. What is necessary is that both the plant protection workers and the farmers should undertake the work seriously and in a well-organized manner. It should also be noted that it is likely that the number of egg-masses may be much more in the vicinity of the spots where the light traps have been set up. Hence, special care should be taken to collect the egg-masses from such areas.

(*c*) If due to some reason, it is not possible to organize a successful campaign for egg-mass collection, then chemical control operation should be resorted to as quickly as possible, at any rate not later than 10 to 15 days after the hatching of eggs when the larvae develop the migratory tendency. In fact, the more the chemical control is delayed, the less effective it becomes. The repetition of this operation will depend on the persistence of the insecticide selected and on the number of waves of moth emergence from the soil as indicated by the light-trap catches.

(*d*) In case it has not been possible to organize control operations and the *Kutra* caterpillars have become full-grown and started migrating from place to place, then, at least a good vigil should be kept to follow their movement and to mark out the areas where they have entered the soil to pupate. Later, when the time of their emergence is near, these areas should be properly treated with a good persistent insecticide so that the moths emerging therefrom get a lethal dose of the insecticide during the process of emergence and while they rest for 15 to 30 minutes on the surface before taking flight. In this connection, it may be noted that the full-grown larvae seek the shade of trees, light loose moist soil particularly along the bunds, and fences i.e. the areas which are ordinarily not likely to be ploughed up or otherwise disturbed. Man should exploit this tendency of the caterpillars while organizing their effective control.

PHADKA GRASSHOPPER

(Plate IV)

The insect pest commonly known as Phadka belongs to the family of short-horned grasshoppers. Cultivators in India are quite familiar with this group as they have been noticing for many years that their crops are damaged by some kind of grasshopper or other. This is evident from the fact that in almost all the important regional languages of India, there are common names for some kind of grasshoppers like 'Vittil' in Tamil, 'Midtha' in Telugu, 'Tid' in Sindhi and Punjabi, 'Pulpondu' in Malayalam, 'Jhitika' in Oriya, 'Jitti' in Kanada, 'Nak-thod' in Marathi, 'Phadka' in Hindi, etc. All these names are used not for the same species but for those different ones that are most prevalent in various regions. The name 'Phadka' is given to one species of grasshopper, viz. *Hieroglyphus nigrorepletus* Bol, the control of which is dealt with in the present section.

Several species of grasshoppers are found in India including the most dreaded and well-publicised Desert Locust which is also a member of the same grasshopper family. Besides the locust, there are four species which are considered to be serious pests of agricultural crops in India. These are : the rice grasshopper[1], a serious pest of paddy; the wingless or Deccan grasshopper[2] and Phadka grasshopper[3] which damage mainly the millet crops; and the surface grasshopper[4] which damages several crops like cotton, pulses, millets, etc.

Accurate data on the extent of damage caused to various crops by different species of grasshoppers are not available in India. Hence, the relative economic importance of different species of grasshoppers is in a confused state. It is, however, likely that on a careful long-range assessment, it may be found that grasshoppers are actually more harmful than even locusts. Locusts, because of their sudden appearance in large numbers, and spectacular and

1. *Hieroglyphus banian* Fabricius
2. *Colemania sphenarioides* Boliver
3. *Hieroglyphus nigrorepletus* Boliver
4. *Chrotogonus* spp.

frightening way in which they invade and devastate the crops, have attracted much more attention than ordinary grasshoppers. The various species of ordinary grasshoppers, on the other hand are endemic in their activity; they appear in varying intensity every year and everywhere. They begin to damage the crop soon after hatching and they continue to do so upto the adult stage. Hence, the cultivators in general become used to them and consider them as an unavoidable evil which must be tolerated. Due to this psychological phenomenon the grasshoppers, in spite of the heavy loss they cause, have not drawn our attention to the extent they should.

The infestation by the Phadka grasshopper can be spotted as in the case of other leaf-eating insects, firstly, by the damage caused to the leaves which these insects start devouring from margins, and, secondly, by the presence of these insects which can be easily observed when the crop is disturbed. Both nymphs and adults do the same kind of damage. In early stages of the pest, the damage to the crop is hardly visible; but subsequently the older nymphs feed on the crops voraciously. The maximum damage to the crops is, however, done in the adult stage in which the insect lives for more than two months. It has been estimated that one adult eats as much as 4-7 times the amount of food that it eats during its six to seven nymphal stages during development. The feeding on the plant is so vigorous that in the case of the maize crop, for example, many plants are reduced to bare stems; the plant growth gets arrested; the size of the plant remains hardly 1 metre against the normal size of 2 to 2½ metres; and the stems become thin. In case of serious infestation, the majority of plants do not produce grains.

Besides direct damage due to the eating of leaves, these insects spoil the leaf surface with their faeces which after rotting leads to the development of fungus. Thus many of the plants become black and unfit even as feed for cattle. Quantitative estimation of the damage done by these insects in case of the maize crop grown for fodder purposes has shown that an individual grasshopper during its lifetime eats about 42 grams (green weight) of maize leaves. Presuming the pest population to be ten insects per sq. metre and the yield of maize fodder 27,500 kg per hectare, the loss

works out at 18 per cent.

The Phadka grasshopper is a serious pest of crops like jowar, bajra and maize. It has also been reported at times to have done serious damage to sugarcane and paddy. Besides these important crops, the list of food plants of the Phadka grasshopper includes Puthkanda[1], Dab[2], Motha[3] and Napier[4] grass.

The Phadka is a major pest in drier areas. It is believed that its permanent abode is in Ajmer-Merwara (now part of Rajasthan State) and other parts of Rajasthan, namely, Kishangarh, Jodhpur, Udaipur and Shahpur. Besides Rajasthan, this pest has also been reported to occur in Maharashtra, Tamil Nadu, Madhya Pradesh, Uttar Pradesh, Bihar and Delhi.

The eggs are laid in soil in the months of September-October. These eggs lie dormant for a period of eight to nine months. It is only after the onset of the monsoon during June-July that active development in eggs is resumed. The young ones which hatch out 10 to 14 days after the onset of the monsoon are encased in a sort of membranous covering which is cast off as soon as these vermiform larvae wriggle out of the soil.

Soon after emergence from the soil and casting off the membranous covering, the young ones now called nymphs begin to feed and grow. This nymphal period lasts upto the end of August or early September when the insects attain the adult stage. During this period, the nymphs cast off their skin six or seven times. After becoming adults the insects take 7 to 20 days (average 11 days) to attain sexual maturity and after the first mating they require a period of about seven days to lay the first batch of eggs. The life as adult lasts for about two months, during which the insects mate, lay eggs, and die. Thus, there is only one generation of this insect during the year.

The most significant peculiarity about this grasshopper is that the egg-laying takes place mostly in uncultivated patches in and around the cultivated areas.

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1. *Dactyloctenium aegyptium*
2. *Vernonia* sp.
3. *Brachiaria* sp.
4. *Pennisetum purpureum*

In-between the cultivated fields the egg-laying takes place on and along bunds and within the cultivated field on raised mounds. The eggs are laid at depths of 5 to 12 cm in the soil in-between the roots of various shrubs generally growing on bunds or mounds. Only a small percentage of egg-pods is laid in the field proper. This peculiar egg-laying habit of this pest is very useful for the survival of the pest because by making proper choice for the site which is not to be ploughed down, the safety of the progeny is ensured. Also, this habit is very important from the viewpoint of control as will be seen later. It has also been observed that a large number of eggs are laid in the soil under the hedges if they are there. On uprooting the shrubs or hedge plants one can observe egg-pods hanging on the secondary roots of the plants dug out. It has been observed that six to ten egg-pods can be commonly collected from the base of one shrub. There is some tendency towards gregariousness at the time of egg-laying. Hence, one may collect a large number of egg-pods from one stretch of a bund and the adjacent portions of the same may be entirely free from eggs though the same kind of shrubs may be growing there.

Having chosen a suitable place, the female grasshopper burrows a hole in the soil by means of the movements of its special organ called the ovipositor which is situated at the anal end of its abdomen. In this burrow, it inserts its abdomen which is very much extended at this time and it is in this way that the insect deposits its eggs at a depth of several centimetres below the surface. Once the female has started egg-laying, it will not withdraw its abdomen from the burrow even if it is disturbed. One can easily catch them in this posture. Before laying eggs the female begins to exude a foamy material secreted by accessory glands and this material envelops both individual eggs as they are laid one by one and the whole egg-mass containing many eggs laid at one time and one place. After completing the act of egg-laying, the female exudes obviously a different kind of material over the egg-mass, withdraws its abdomen from the burrow and plugs the hole with a little loose soil. The foamy material exuded by the female serves for sticking the eggs together and for cementing the soil particles which constitute a hard pod-like structure with eggs within. The material exuded on the top of the egg-mass serves as a kind of loose plug for the

burrow containing the egg-pod. The plug material gets dried up very soon and turns into a fluffy, brownish, wool-like substance. On taking the egg-pod out from the soil, this woolly material gets detached. Two to six egg-pods are laid by each female and each pod contains, on an average, about 40 eggs. The egg-pod has a coating of earth all round; it is elongate in shape with a slight bend at the middle; the upper end is somewhat concave. The outer coat of the egg-pod is very hard and the thus eggs inside it remain secure.

After hatching from the eggs, the young vermiform larvae wriggle out of the soil by making movements with the help of the abdomen. The first vermiform larva makes a very fine bore of pin-head size and gets out of the soil. Thereafter through the same bore other larvae from the same egg-pod follow one after the other. Having come out, the vermiform larva lies prostrate upside down with its back in contact with the soil, and then it starts freeing itself from the fine membranous covering which is thus cast off. This process takes hardly half a minute. These cast-off skins are found round about the holes through which the nymphs have freed their way out. If careful observation is recorded in time these skins can indicate, firstly the place where hatching has taken place, secondly the number of egg-pods from which hatching has taken place and, thirdly, a fair idea of the number of insects that have emerged.

As mentioned earlier, the eggs laid in the soil during September-October lie dormant till onset of the monsoon. The development in the eggs is resumed when it begins to rain during the monsoon season and hatching takes place during June-July. If there is no rain up to August, then there is no hatching during that season and the eggs continue to lie dormant till the next monsoon season. The intermittent early rains during April-May do not bring about hatching of eggs. Also, the rains during the season should be well distributed; a long spell of drought particularly in the initial stages retards or affects adversely the hatching of eggs.

If in a grasshopper-infested locality the rains fail in a particular season, the pest will not be observed in appreciable numbers during that year. In such cases it should not be concluded that the pest has been eliminated from the locality; some of the eggs of

this pest remain viable up to three years. It has been found that the viability percentage remains up to 70 in case of eggs which have remained dormant for two successive seasons and it falls to about 34 after three seasons of dormancy. Thus, these insects can survive two consecutive dry years and can reinfest the crop during the third year provided the conditions turn favourable in that year.

The eggs are laid on bunds and mounds. It has been observed that by dismantling and remaking these bunds, the original position of egg-pods in which these are laid gets disturbed. Experiments have shown that this disturbance has an adverse effect on hatching of eggs as the nymphs are not able to emerge out of the soil particularly from the egg-pods which get buried in the inverted position as a result of physical disturbance of the soil. Also, very few nymphs are able to reach the soil surface if they have hatched out of the egg-pods which lie buried in a sideway position. Thus, these physical disturbances are harmful for successful emergence of nymphs.

Normally, these insects lay eggs in the soil at a depth varying from 5 to 15 centimetres and the nymphs are also normally able to come out from this depth, obviously because the bore, formed by the mother grasshopper while laying eggs at such a depth, is filled with relatively loose soil. The conditions change materially when the soil is disturbed by cultural operations. Experiments have shown that the nymphs which hatch from egg-pods buried in compact soil at a depth of more than 5 cm are unable to come out. Thus, by undertaking cultural operations in the field, not only the normal position of egg-pods gets disturbed but also the burrows in the soil get closed and as a result of these disturbances the nymphs are not able to emerge out of the soil.

Studies on the peculiarities of the habits and life-history of the Phadka grasshopper have revealed the following rational approaches for keeping this pest under check and for reducing its damage in the cultivators' fields. The different steps mentioned below are such that any one of them can be so successful as not to necessitate the next step. However, as the success of each step has to depend on the intensiveness and extensiveness of the operations carried out, it is likely that all these steps may have to be carried out in succession to ensure complete success.

1. As mentioned earlier, the majority of eggs are laid in the soil which is generally not cultivated, *i.e.* either in uncultivated areas or on bunds and mounds within the cultivated portion. Due to this peculiarity, it becomes necessary to reduce the uncultivated area as much as possible. Reclamation of cultivable wasteland should reduce the intensity of the problem posed by the Phadka pest. Particular attention should be paid to level down all the stray mounds in the fields.

2. It has been shown beyond doubt that mere mechanical disturbance of the soil wherein the Phadka eggs have been laid, immensely reduces the chances of successful emergence of Phadka nymphs. Hence, it is advisable that before the monsoon begins, the bunds are scrapped to a depth of about 15 cm and reformed.

3. After the onset of the monsoon a period of about one week has to lapse before the Phadka nymphs emerge out of the soil. This period should be utilized for treating the egg-infested areas with persistent insecticides which would kill the nymphs as soon as they emerge. BHC (10%) and aldrin (3%) dusts have been found to be effective.

4. For a period of two weeks after emergence the nymphs remain confined in the area where they emerge. This period should be utilized for direct application of the insecticides. In the cultivated area, this operation should be carried out only along bunds where the nymphs are concentrated instead of treating the whole field, and the bulk of insecticidal dust thus saved should be utilized in treating the uncultivated areas in the vicinity of the cultivated fields. This is the most critical stage for ensuring successful control of this pest, firstly, because at this stage, the pest is confined to a comparatively much smaller area which has to be treated and secondly because this stage is much more susceptible to insecticides than later stages.

5. It should be clear from what has been stated above that the control of the Phadka grasshopper is much easier and cheaper in the early stages than later on when it enters the cultivated fields. In view of this special consideration, it becomes necessary that the control of the Phadka grasshopper should be organized on a co-operative basis, particularly in the uncultivated areas in the village.

6. If the above-mentioned operations are carried out properly,

the chemical control of the pest on the cultivated crops may not be necessary. However, in case the crop has to be treated, special care has to be taken for ensuring complete coverage of all the leafy portions, particularly the leaf whorl. This is necessary because the pest has the habit of confining itself in whorls and under the leaves.

CHAPTER II

PESTS OF PADDY

THERE are more than three dozen potential pests of paddy but the five which cause most serious damage to this crop are: (*a*) the stem borer, (*b*) the swarming caterpillar, (*c*) the rice bug, (*d*) the gall fly, and (*e*) the brown plant hopper. The rice grasshopper is also often quite serious but the same is not being described in this chapter as an example of grasshopper has already been described earlier as a polyphagous pest

THE STEM BORER

(Plate V)

Half a dozen different species of lepidopterous larvae bore into the tissue of the paddy plant. Out of them the one which causes great concern in India is *Tryporyza incertulas* (Walker). The interesting point about this species is that unlike other lepidopterous larvae this is highly monophagous and no alternate host plant besides rice has been recorded so far. It is found in practically all the rice-growing regions of India and in many rice-growing tracts of the world but the number of generations it completes during the year as also the amount of damage it causes vary from place to place, depending on the agro-climatic complex of the region.

The adult stage of the pest is a moth with wings of ocherous yellow colour. In the female there is a prominent black spot on each of the forewings, while this spot is not quite clearly discernible in the males. The eggs are laid in batches which are covered by buff-coloured hair contributed by the anal tuft of the female moth. These egg-masses are prominent enough to be easily spotted out and collected. The first-stage larvae hatching out from the egg masses crawl about on the plant or hang down from the leaves by a silken thread. Soon thereafter they cut open a small hole in the stem of the paddy plant and enter the plant tissue remaining there for the rest of their life as larvae and pupae. The larva feeds

inside the stem and attains the length of about 2 cm. When full-grown, it has a smooth surface of pale yellowish colour at times with a greenish tinge. The head is orange-yellow. Before pupation it cuts open another hole through which the moth ultimately comes out. This is an interesting example of planning two stages ahead, by the larva, *i.e.* for the convenience of not only the immediately next stage—the pupa—but also of the third stage—the adult. The larva spins a silken lining inside the burrow where it will rest as a pupa and constructs a comfortable silken cocoon before it enters the life of quiscence. After the pupal period is over, depending on the prevailing temperature, the moth emerges and makes the beginning of the next generation. The moths are attracted to light.

As regards the damage done to the paddy plant the whole seedling dies if the infestation comes early. Later, the whole attacked tiller suffers the adverse effects of the larva feeding inside the stem; it turns yellow and produces a dead-heart. When the infestation occurs at a still later stage, the earheads become white and grain remains chaffy.

It should be clear from the foregoing peculiarities of the life-history that the points at which the pest can be attacked with advantage are the egg-stage when egg-masses can be mechanically collected and destroyed, the time of hatching when the first-stage larvae can be killed by contact poisons before they have time to enter the plant tissue, and then the adult stage when moths fly about and are attracted to light. Some efforts have also been made to kill the larvae when they are inside the stem by means of systemic poisons. However, as this is not the only pest of paddy, the full control strategy will be discussed later.

THE SWARMING CATERPILLAR

(*Spodoptera mauritia* Boisduval)

(*Plate VI*)

This is a sporadic pest but very serious indeed whenever it appears in large numbers. Not only it is a serious pest practically in the whole of the coastal regions of India but its distribution is

spread over large tracts of oriental and Australian regions and is reported from even west Africa. As the name indicates, in caterpillar stage this pest has a tendency to migrate from field to field in large swarms. The swarm practically browses a field like cattle and when one field is completely finished, the swarm marches on in regular army formation to the adjoining field. Hence, this pest is also referred to as army-worm. The caterpillar is essentially a polyphagous species feeding on a number of cultivated crops and wild grasses but paddy is the most important crop in coastal areas the climate of which is particularly suitable for this pest. Hence, it turns out to be a serious pest of paddy. Also at times it can so happen that the younger stages of the caterpillars are passed among wild grasses in uncultivated areas where nobody notices their presence and from there they may suddenly march into the cultivated fields like an invading army.

The number of generations varies in the different regions of the country. Thus, in Bengal it attacks Boro paddy during February-March and Aus and Aman paddy from May to October. It is claimed that a prolonged period of drought for a month or more followed by heavy rainfall produces conditions favourable for the outbreak of this pest.

The adults of the pest are medium-sized noctuid moths of grey-brown colour with beautifully designed forewings which have a wavy border pattern on the fringe. The hind wings are practically white. These moths lay eggs in large masses each containing upto several hundred eggs. These egg masses are covered with buff-coloured hair from the female's body and are found on all kinds of low plants both in cultivated and uncultivated areas. They stand out prominently against the green background of the leaves. The eggs hatch within a week or so depending on the prevailing temperature and the young larvae immediately begin to feed on the nearest available plant. The larval stage lasts three to four weeks during which the first-stage larva which at first is only a few millimetres in length gradually grows through several moults into a full-grown larva of 3 to 4 cm in length. The colour pattern of the larvae consists of longitudinal stripes which in the beginning have a mixture mostly of green and yellow with a reddish stripe along the side and which later on

are mostly of yellowish brown hue. Both the moths and the caterpillars are nocturnal in their activity and remain mostly in hiding during bright daylight. Pupation takes place in the soil. Hence, one may at times find that the whole army of caterpillars suddenly disappears and the farmer may feel that the trouble has come under control till the next generation suddenly appears once again. The pupal stage lasts generally from 10 to 12 days after which the moths of the next generation appear and give rise to a new brood.

As regards the methods of controlling this pest, it will be seen from the foregoing account of its life-history and peculiarities that the most rational approach for preventing damage by the swarming caterpillar is to be on the look-out for the egg-laying by the moths and to get the large prominent egg-masses collected and destroyed. The only snag in this approach is that the egg-masses are laid both in cultivated and uncultivated areas. Hence, collection of egg-masses has to be carried out all over the area and as a large scale co-operative operation which may form part of an overall integrated pest control campaign. The case is similar to that of *Kutra* discussed earlier. If, however, for some reason or the other it has not been possible to tackle the pest at the egg-stage and hatching has taken place, then chemical control has to be expedited so as to kill the pest as soon as possible and before it is able to do irrepairable damage. For this purpose, any good insecticide having either stomach poison effect like various inorganics or a combination of contact and stomach poison effect as several organic insecticides will do. In earlier days, when powerful insecticides were not available the recommendation generally used to be to flood the field with water and surcharge the same with kerosene oil and drag a rope across the crop so as to make the caterpillars fall in kerosenized water and die. The third and still more difficult situation arises when the pest is not subdued in its early stage and it is allowed to form invading armies of large swarms. At this stage a much stronger and quick-acting chemical like some organo-phosphorus compounds will be needed to be used against these swarms. Also, under such situations if a farmer finds that some of his fields are still free but are likely to be invaded, then he can save his crop by making a

steep trench round his own fields and the effectiveness of these trenches can be enhanced by letting in water and kerosenizing the same. This is certainly not a solution for plant protection staff but it is a tool for an individual cultivator when large-scale co-operative endeavour is not practicable.

GUNDHI BUG

[*Leptocorisa oratorius* (Fabricius)]

(*Plate VII*)

It is the most serious bug pest of the paddy crop. The name *Gundhi* is derived from the Hindi word *gundh* which means unpleasant odour and the insect has got this epithet because of the offensive odour it emits. Although it feeds on a variety of plants including small millets, wild grasses, etc. it creates serious concern when grain-formation is in progress in the paddy crop. The milky stage of paddy grain is its chief target. The bug sucks out the milky juice, leaving the white chaffy husk in seeds on the earheads. In cases of severe infestation, practically all the grains of all the earheads become chaffy. The pest remains breeding in appreciable numbers scattered among wild grasses, in uncultivated areas including the field bunds, etc. and it is attracted in large numbers to the paddy crop when the latter is reaching the milky grain stage. Hence, the trouble appears to occur rather suddenly.

The *Gundhi* bug is found in most of the rice-growing areas of India and its distribution extends over the whole of South-East Asia from China and Japan in the north to Sri Lanka in the south. It is also found in the Philippine Islands and Australia. However, in India its attack is specially severe in Uttar Pradesh and Bihar.

The adult bug is a long (about 15 mm) slender insect with much longer legs. The colour-pattern consists of a mixture of green and brown, the younger being more greenish and the older ones more brownish. It lays blackish-brown small bead-like eggs in long string-like rows on the leaf blades of its host plants both in cultivated fields and uncultivated areas. Depending on the prevailing temperature, these eggs hatch in about a week's time and the young

nymphs appear to be practically all legs. They immediately begin to suck the plant juice and continue damaging the plants during both nymphal and adult stages. Total life cycle occupies 15 to 30 days with five generations in a year.

Control measures suggested in earlier days, though some what tedious, were undoubtedly effective. These were either of a mechanical nature like bagging the bugs or of a cultural nature like clean cultivation, etc. Now, after the discovery of so many strong contact insecticides, it is possible to knock out the pest by spraying or dusting any of the available modern contact insecticides. The choice of the insecticides has to depend mostly on price, avilability and possible residues at harvest. As the bugs can fly from field to field, the main factor determining the degree of success is the large size of contiguous area over which control operations are carried out by co-operative or governmental agencies. Even preventive measures are feasible by organising large-scale campaigns both in cultivated and uncultivated areas; these have to be carried out one or two weeks before the paddy crop reaches the milky stage in the uncultivated areas and at the milky stage in the cultivated fields.

THE GALL FLY

[*Orseolia oryzae* (Wood-Mason)]

(*Plate VIII*)

As the name indicates, this pest is a small fly with long slender legs and its damage on paddy plants results in the formation of long tubular galls of silvery appearance in place of the normal stems with earheads. Hence, the crop attacked by this insect is said to be suffering from the silver-shoot disease; this malady has different names in the different regions of the country. The pest is a dipterous fly with a wing-span of less than 2 mm. Its distribution covers west Africa, Sudan, Pakistan, India, Bangladesh, Sri Lanka, South-East Asia, south China and Papua New Guinea. In India, it attacks the paddy crop with varying intensity in most of the paddy-growing areas but its incidence seems to be particularly high in the hinterland of the coastal regions of the country extending up to areas like Bihar.

The fly breeds on a number of wild grasses and it is attracted to the paddy crop particularly at its tillering stage. The female fly lays reddish elongated eggs about 0.5 mm in length generally on the lower surface of the basal portion of the leaf. The tiny larva hatching out within 3 to 5 days creeps down between the leaf-sheaths till it reaches the apical point of the central shoot or the tiller, as the case may be, and there it enters the tissue and destroys the growing point. The result is that normal growth stops and a small tubular gall is produced presumably due to some kind of physiological disturbances caused by lacerating the cells. This gall gradually elongates and a long hollow shoot of silvery appearance emerges in the place which in a normal plant is occupied by the stem bearing the earhead.

In the meantime, the larva becomes full-grown in about 10 days and pupates inside the tubular gall. The pupal period lasts for only 3 to 5 days and thereafter the fly emerges out of the gall through a hole already made before the pupal stage. Thus, the whole life-cycle takes only about three weeks. The result is that the fly is again ready to infest the new tillers formed as a result of its attack on the central shoot. Hence, successive generations of the pest continue to attack the same crop and in cases of severe infestation a very large percentage of the plants may yield no grain at all.

In view of the peculiar biology of the gall fly which spends the major portion of its existence inside the gall, its control has been posing serious problems. The adult is the most vulnerable stage but action against this stage has to be so precisely timed as to coincide with the emergence of the brood and it should remain effective throughout the period of emergence. The collection and destruction of the galls, i.e. the *silver-shoots*, can also help provided it is started fairly early in the season and the galls are rogued out as soon as these are visible. This operation has to be quite early because by the time the gall outgrowth begins to be visible, the maggots will generally have reached the pupal stage and once the fly emerges out the removal of the gall becomes mere waste of labour and expenditure. Also, strong penetrating insecticides like the organophosphates ones can be applied through irrigation water, provided enough precautions are taken to avoid the hazards of contaminated water standing in the field. Also, some new varieties of paddy

have proved to be resistant to this pest and growing these varieties in endemic areas should be encouraged.

BROWN PLANT HOPPER

[*Nilaparvata lugens* [Stal)]

The brown plant hopper, can be quoted as one of the classical examples of how our over-enthusiasm to develop new high-yielding varieties of crops has resulted in near catastrophe. This plant hopper was considered to be of minor importance on traditional local varieties. After the release of high-yielding varieties, it has been periodically appearing in epidemic form in the rice growing areas of India and other countries of tropical Asia.

Investigations have shown that reasons for increased activity of brown plant hopper are the introduction of high tillering dwarf plant types, close spacing, high doses of nitrogenous fertilizers, good water management and double or continuous cropping. All these factors are highly favourable for rapid multiplication of the pest. The outbreaks are regulated by climatic factors, particularly rainfall and the associated relative humidity.

Adult and nymphs of the hoppers exhibit negative phototaxis and prefer high humidity. They confine their activity in the basal region under protected conditions provided by close luxuriant plant growth. They damage the plants by sucking plant sap and plugging vascular bundles with their feeding sheaths. The infested plants start drying and a condition, commonly known as 'hopper burn', appears initially in patches, which ultimately join as population increases. In addition to damage by sucking, this pest has also been found to be responsible for spreading a newly identified virus disease called 'grassy stunt' or 'ragged stunt'.

The females lay eggs by lacerating the leaf mid ribs with their sharp ovipositors. Eggs are cylindrical and transparent and are laid in clusters of 4 to 10 with anterior ends attached to one another. Each female may lay 300 to 350 eggs.

Young nymphs are dark brown in colour, 0.5-0.6 mm long when freshly hatched and 18-20 mm when full grown. Eggs hatch in 8 to 9 days and nymphs take 12 to 14 days to reach the adult stage.

Adults are uniformly brown in colour. There are two distinct winged forms: macropterous with normal wings which are well adapted for migration; and the brachypterous, with wings very much reduced in size, the hind wings being rudimentry. The latter is relatively larger in size, has longer legs and ovipositor. Adults may live for 10 to 20 days. Flight dispersal from one area to another generally takes place before the egg deposition stage on the evenings of hot humid days.

Chemical control by spraying with contact insecticides has not proved to be effective. Carbofuran, a new systemic insecticide, applied as granules is reported to give satisfactory control of the pest. A number of varieties, viz. Mudgo, TKM6, Parijat, Shakti and Triveni have been identified and developed. The incidence and damage by the pest is very low on these varieties.

Control Schedule against Pests of Paddy

As stated earlier, there are more than three dozen potential pests of paddy but only a few actually cause serious concern to the farmer. There are three major characteristics of the paddy crop which should be kept in view in evolving a rational control schedule for this crop. The first two characteristics of the paddy crop are rather disadvantageous. Firstly, not only is the paddy crop in many places grown as a one-crop rotation—paddy following paddy—but often as many as three crops a year are taken on the same fields. This unbroken continuity of the same crop creates ideal conditions for the development of the paddy pests. Hence, very great care is necessary to keep the pest problem under control in the case of paddy. Secondly, not only is there continuity in time, i.e. paddy after paddy up to three crops in a year but there is continuity in space also because the land used for paddy is in many places not quite fit for other crops. In other words, paddy cultivation is continuous both in time and space and these factors are very conducive to pest multiplication. The third characteristic is very helpful. Often the paddy seed is first sown in nurseries and later the seedlings are transplanted. This fact should be fully exploited for the control of paddy pests and an effort should be made to nip the trouble in the bud. While the crop is in the nursery, its acreage is

much smaller than that of the transplanted crop. Hence, the control measures will be less costly and more effective at the nursery stage. Further, at the transplanting time practically each seedling is individually handled and with a little extra care it should be possible to eliminate the affected seedlings and clip the prominent egg masses of certain pests and also to treat the seedlings against certain other pests. A number of paddy pests are multivoltine and consequently the adult flying stage comes again and again in the same season. Also, the univoltine species like grasshoppers are capable of migration. It is, therefore, necessary that farmers are made fully aware of the fact that control measures carried out in a few fields will not yield the desired result unless all the farmers pool their resources and carry out the control operations on a co-operative basis.

A. Regular Preventive Items of the Schedule

The following items should be included in the regular agricultural operations for successfully growing the paddy crop:

1. As a number of rice pests like *Spodoptera*, gall fly, Gundhi bugs, *Hispa*, etc. breed on grasses during the off-season, it should be a definite policy of the rice-growers to keep their area free from such wild grasses.

2. As preparatory operations for rice cultivation, proper ploughing and destruction of stubbles are necessary to kill such stages of paddy pests as caterpillars and pupae of the stem-borer in paddy stubbles, pupae of swarming caterpillars and eggs of grasshoppers. In areas where grasshopper trouble is likely to be serious, scrapping of the bunds should also be attended to as a regular routine.

3. Light traps should be set up right from the beginning not only to attract and destroy the moths but also as indicators of the activity of these pests in the field so that timely control operations can be carried out. It should, however, be borne in mind that sometimes the area in the immediate vicinity of the light trap gets more severe infestation. The moths are attracted to light from the surroundings and those of them which escape the trap can cause severe damage round about the light trap. As a precaution against such an eventuality the area in the immediate vicinity of the light trap should be specially treated with suitable persistent contact insecticides.

4. Right from the early stage the fields should be inspected regularly for the appearance of prominent egg-masses of the stem-borer and swarming caterpillar and as soon as these egg-masses appear, they should be collected and destroyed. It should be noted that destruction of egg-masses is the surest and most economical way of controlling these pests especially in the case of the stem-borer, wherein stages other than the eggs are far more difficult to destroy. Also, during these inspections, care should be taken to observe, collect and destroy the characteristic dead-hearts due to the stem-borer, silver-shoots due to the p addy gall fly and also the tunnels in leaves containing immature stages of the rice Hispa. Thus, vigilant farmers, if they work in co-operation, can confidently hope to nip in the bud the infestation of all these five important paddy pests.

5. The operations mentioned under item 4 should also be carried out at the time of transplanting the paddy seedlings, i.e. after the seedlings have been uprooted from the nursery and before they are planted again in the field; or, in other words, when the seedlings are collected together in convenient boundles. At this stage the seedlings can be thoroughly treated with a suitable persistent insecticidal dip so that these seedlings may carry an effective insecticidal film on their surface. Some workers have suggested a dip in some systemic insecticide for protecting the crop from most of the pests.

6. The swarming caterpillars and cutworms can also be checked from entering the field from outside by means of a trench round the field.

B. Control Operations to be Carried out as and when Necessary

1. The crop and bunds should be treated with a suitable insecticide, say 5% BHC dust, whenever any of the surface-feeders like the *Gundhi* bug, the grasshopper, etc. increase in numbers beyond tolerable limits.

2. The cutworms and swarming caterpillars can also be destroyed by flooding the field. A little oil (about 6 litres per hectare) may be mixed in the flood water but it will be better if a suitable insecticidal emulsion is substituted in place of oil. Even *Gundhi* bugs can be made to fall into this oily water by moving a light bamboo stick or rope, horizontally over the plants.

CHAPTER III

PESTS OF WHEAT AND BARLEY

COMPARATIVELY much more information is available for wheat than barley. Hence, although the following account is mainly for wheat it is also quite applicable to barley. In India, these cereal crops have been comparatively free from insect pests in the field, although there are some very serious pests of these crops in other parts of the world, e.g. the hessian fly (*Mayetiola destructor*) and the wheat stem sawfly (*Cephus cinctus* Norton) in America and the bug *Eurygaster integriceps* in Russia. In India, the most serious pests of the wheat crop are the termites, the damage due to which is particularly heavy in light soils and unirrigated areas. Other pests which have caused concern to cultivators in some areas at times are the stem-borer (*Sesamia inferens* Wlk.) in Madhya Pradesh, the aphids (*Toxoptera graminum* R.) in Maharashtra, the Gujhia weevil (*Tanymecus indicus* Fst.) in U.P. and jassids in M.P. Also, such polyphagous insects as the armyworms (*Cirphis loreyi* Dup. and *C. unipuncta* Haw[1].) and cutworms like *Agrotis ipsilon* (Hufnagel) and *Ochropleura flammatra*. Schiff and *Euxoa spinifera* Hubn. and surface grasshoppers like *Chrotogonus* spp. have been listed as pests of some importance for crops including wheat. These seem to be now affecting new high-yielding varieties.

However, on the whole it can be safely stated that insect pests have not been acting, at least in the past, as a limiting factor in increasing wheat production in India specially in irrigated tracts. But this relative freedom of the wheat crop from insect pests in the field is more than compensated by the heavy loss which wheat grain suffers from insect pests of storage which have been dealt with separately. In fact in India on the whole, the wheat crop has been as free from insect pest problems in the field as it is beset with them in storage; the reverse is the case with paddy. However, this

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[1] Recently, it has been proposed to change the name of this insect to *Mythimna separata* Walker.

so-far comfortable position regarding insect pests of the wheat crop is fast disappearing with the increasing tempo of intensive cultivation of high-yielding exotic varieties.

There are two major insect pests of the wheat crop in the traditional wheat growing areas of the country: (*a*) termites, and (*b*) *Gujhia* weevil. The damage caused by termites and the *Gujhia* weevil especially in the early stage of the crop, looks more or less alike because both the pests attack the root system of the plant and due to this injury the affected plant begins to dry up. When such symptoms of attack are noticed, one has to dig out a few plants and carefully examine the soil and detect the actual culprit. Later on, however, adult *Gujhia* weevils can be easily seen nibbling the edges of leaves. The termites, or white ants, as they are commonly called have already been dealt with earlier as the pests which cause serious damage to several crops. Hence, only the *Gujhia* weevil is being described here.

GUJHIA WEEVIL

(*Tanymecus indicus* Faust)

This pest has assumed serious proportions during recent years. Its sporadic attacks have been reported from various parts of India like the Punjab, U.P. and M.P. in the interior and also from Assam, Bengal, Tamil Nadu and Maharashtra. Actually it is a polyphagous pest attacking wheat, barley, gram, pea, poppy, maize, rice, etc. and its severe epidemics have sometimes necessitated resowing of various crops.

The adult is a small blackish weevil (4 to 8 mm×2 to 3 mm in size). Its life economy has not yet been fully investigated. However, it is certain that it lays eggs in the soil and both its larval and pupal stages are spent in the soil; only the adult comes up to damage the aerial portions of the plants. But the adult also spends quite some time lurking below clods of earth. Both during the larval and adult stages, the insects damage the roots of the plants. They cut the seedlings at or below the soil surface. In view of these known facts about the life and mode of damage by this pest, two methods of control are possible against

this enemy. One way is to treat the soil with persistent insecticides which can continue to poison the underground stages and also the adult weevil when it goes into the soil for hiding or damaging the roots. The second approach is to treat the aerial portion of the crop with a persistent insecticide acting either as a contact insecticide or as a stomach poison or as both.

Keeping the two major pests of wheat crop in view, it is necessary that the farmers adopt the following control operations:

(*a*) *Soil treatment :* Since both the termites and weevils damage the wheat crop mainly during the seedling stage, an application of aldrin, heptachlor or chlorodane dust at the rate of 20 kg per hectare used in furrows at the time of sowing will protect the crop mainly against the termites and also to a certain extent against the Gujhia weevil.

(*b*) *Dusting against the Gujhia weevil :* If *Gujhia* weevil damage is observed at a later stage, the crop should be dusted with 5% BHC at the rate of 15 to 20 kg per hectare and the dust raked into the soil upto about 10 to 15 cm.

CHAPTER IV

PESTS OF MAIZE AND MILLETS

MAIZE and millets suffer damage from a large number of insect pests but all are not of the same importance to different crops or to the same crop in different parts of the country. Of these, only a few, viz. (*a*) the maize stem-borer, (*b*) the shoot fly, and (*c*) the earhead bug are described below. The hairy caterpillars and the grasshoppers have already been described earlier.

THE MAIZE STEM-BORER

[*Chilo partellus* (Swinhoe)]

(*Plate IX*)

In earlier days the moth-borers of sugarcane, maize, millets and other wild plants of the grass family were all referred to as species of the *Chilo* complex. Consequently all these borers used to be dealt with together. Detailed studies during later years revealed that the so-called *Chilo* complex actually contained a large number of genera and species with very significant differences in their host preference and also in the finer details of their habits and idiosyncrasies.

The moth-borer with its Latin name *Chilo partellus* (*zonellus*) Swinhoe is a very serious pest mainly of maize and sorghum and it attacks these two crops in practically all the tracts of India where these crops are grown. However, it is also known to infest to varying degrees a very large number of other cultivated and uncultivated plants like sugarcane, various millets, paddy, Johnson grass, etc. The distribution of this species extends in this region of the world from Afghanistan to Indonesia and Taiwan in the east and Sri Lanka in the south and it has also been reported from east Africa.

The adult stage of this pest is a medium-sized moth with a wing span of 25 to 30 mm. The forewings are pale straw-coloured, while the hindwings are dull white in colour. These are nocturnal

insects and during the day they remain concealed under dried leaves, clods of soil, etc. They lay, generally on the under-side of leaves, small flatish oval eggs creamy-white in colour and overlapping one another in disposition. The hatching of eggs takes place when they are 2 to 5 days old. The freshly-hatched tiny larvae (about 2 mm in length) begin to feed gregariously on tender leaves, particularly in the central whorl, which later emerge out in a severely fenestrated condition. Thereafter, the larvae migrate to neighbouring plants to enter the stems. In the case of younger plants wherein sufficient stem formation has not taken place, the growing point and the base of the central whorl get badly damaged, resulting in the drying up of the central whorl and forming what is commonly called a 'dead-heart'. This condition does not occur in the later stage when the stem is so thick that even a large number of larvae can continue to tunnel therein. Hence, the attack in the earlier stages of the crop is more spectacular and causes more concern than in the grown-up crop. In fact, in the later stages of the crop at times the farmer is likely to be misled into thinking that there is no infestation in the crop or that the infestation has come under control, while actually serious damage may be in progress within the stems of the individual plants without showing any external sign.

During the normal *kharif* crop season, the larval stage lasts for four or five weeks although in the winter of cooler regions it may extend even to six months or more. Also, it is in this prolonged larval stage that the insect passes the unfavourable winter season. The pupation takes place within the stem and the pupal period lasts from a couple of days to more than two weeks. The moth emerges from the stem through a hole made earlier by the larva before it pupates.

There are several generations from early spring to late fall when the pest enters hibernation in the larval stage. The hibernating larvae live either in the stubbles or in the harvested stems.

As regards control, the weaker strategic points in the life-cycle at which this pest can be attacked are mainly the hibernating larval stage in the stubbles and harvested stems at which the pest can be destroyed by making sillage of the harvested stems and collecting and burning the stubbles and the moth stage when it

alights on the plant to lay eggs when it can be killed by means of residual films of a persistent insecticide. The same insecticidal film can also kill the first-stage larvae before they enter the plant tissue. However, the first-stage larvae have a tendency to concentrate in the central whorl and this habit has recently proved to be of great value in their control. Now the best way of dealing with this stage is to place granules of contact insecticides in the central whorl. These granules remain for quite some time in the leaf axis and continue to kill the first-stage larvae. Of course, granule application has also to be repeated at suitable intervals like spraying and dusting. No chemical treatment can be of any use when the larvae are inside the stems of the standing crop. However, parasites which attack larvae inside the stem can be made use of but the availability of a sufficient number of parasites is practically nil. Promising work is in progress for evolving maize and sorghum varieties resistant to this pest.

THE SHOOT FLY

[*Atherigona soccata* (Rondani)]

This pest belongs to a group of dipterous insects called Muscid flies. Some species of this group are pests of various cultivated and wild plants of the grass family, while others are saprophytic, breeding in rotting organic matter.

The sorghum shoot fly in its adult stage looks in general contour like the housefly but it is much smaller in size (about 3 mm in body-length). These flies love sunlight and have a comparatively long adult life of about a month or more. They feed on honeydew and other sweet material available in nature. They lay eggs singly on seedlings which are generally not more than 15 to 20 cm in length. Each fly lays up to 40 eggs but in a number of short spells of one or two days at irregular intervals. The eggs are very peculiar in shape. They are elongate, flattened and somewhat boat-shaped and they are provided with two wing-like lateral projections along the longitudinal margin while the main body of the eggs is characteristically sculptured. Within two days or so the egg hatches into a very tiny maggot tapering at one end. The maggot creeps down within the leaf sheaths till it reaches

the base of the seedling. There it bores into the axis of the seedling and destroys the growing point and the base of the central shoot, causing the characteristic 'dead-heart'. After spending about a week in the larval stage, the maggot pupates in a small barrel-shaped puparium lodged within the axis of the seedling which by now is completely dried up. A few non-productive tillers may arise or the seedling as a whole is killed. The pupal period also lasts for about a week after which the adult fly emerges and starts laying eggs on other seedlings.

There are different shootfly species which attack other millets like *bajra*, *ragi*, fox-tail millet, etc.. However, their biology and nature of damage are similar.

Earlier the only feasible recommendation for the control of shoot fly was to uproot systematically all the affected seedlings as soon as the sign of attack was discernible and as an advance preparation for this roguing operation, to increase the seed-rate, so that the plant population may not become too low after roguing. In recent years, however, it has been found that certain insecticides with systemic action, if applied at the time of sowing, keep the seedlings free from this pest. An effective seed treatment has also been developed.

EARHEAD BUG

(*Calocoris angustatus* Lethierry)

(*Plate X*)

This is a very serious pest particularly in certain parts of south India. Athough it has been reported to damage a number of cereals and grasses, the sorghum crop is its main host, suffering considerable losses in grain-yield.

In the adult stage this Capsid bug is about 5 mm in length, a little more than 1 mm in breadth and yellowish green in colour. It first attracted the attention of entomologists in India as early as 1893. Although a number of other somewhat similar-looking bugs remain associated with the population of this pest in the field, they are generally of minor importance.

The adults are attracted to the sorghum crop as soon as the earheads begin to make their appearance from the enfolding leaf sheaths. They insert their long (about 1.5 mm) cigar-shaped eggs generally under the glumes or even in-between the anthers of the sorghum florets. These eggs hatch out mostly in less than a week. As each insect lays between 150 and 200 eggs, the population of the pest increases by 75 to 100 times within about a week since the crop also attracts the adults from the surrounding uncultivated grasses. This huge army of young tiny nymphs soon after hatching begins to suck out the juice from the just-developing sorghum grains which are in the milky stage at that time. The result is that the grains instead of setting in the normal course become chaffy or at least get shrivelled. At times the whole earhead becomes at first blackened and then in due course gets dried.

Within a period of a little over two weeks, the tiny first-stage nymphs, having yellow and orange-red colour bodies, develop to the adult stage through five instars; and in less than three weeks from the first egg-laying, the new generation is again ready to oviposit on many more earheads which are still in the tender receptive stage. Eggs are not laid when the grain becomes hard. All the same, at least two generations can feed in the same crop as all the earheads do not ripen at the same time. The damage could be much more serious than what is observed but for a bacterial disease which is reported to bring about considerable mortality at the adult stage.

The control of this pest was very difficult in the past but now any good contact insecticide should do the job provided it is applied at the right time.

Control Schedule

Taking into consideration the serious nature of some of the insect pests and potential dangers from other insects to millet crops, the policy of millet-growers should be to evolve a co-operative routine schedule of control operations on the following lines:

(1) The harvested stalks of millet plants should be used up as soon as possible and in any case before the end of the winter season as the stalks harbour various stages of borer pests.

(2) For the same reason as mentioned above, the stubbles should be dug out and destroyed. It might be advisable to plough the fields just before the beginning of the summer season so as to uproot the stubbles which should be collected and used up as fuel or burnt if not needed as fuel. Ploughing will also disturb and expose the egg-masses of grasshopper pests and pupae of caterpillar pests to sun and predators. The bund of the fields and the ground round the trees and fences should also be scrapped, ploughed or hoed as such places specially harbour these pest stages. Also, the grasses on the bund should be used up or destroyed along with the pest stages.

(3) While sowing the crop use a higher seed-rate so as to be able to uproot later the plants affected by insects without decreasing the plant population below the optimum level.

(4) The crop should be inspected regularly from the very early stages for the appearance of (*a*) dead-hearts due to borers of any kind, (*b*) moths emerging from pupae which have been under diapause and which escaped operation No. 2, (*c*) egg-masses laid by these pests, and (*d*) other external feeders. In the same round of operations the dead-hearts, the egg-masses and the sluggish moths should be collected and destroyed.

(5) Chemical control operations should be carried out according to the nature and intensity of the pest. For sucking insects, a strong contact or systemic insecticide should be used. But if there is also an infestation of leaf-eaters like caterpillars and grasshoppers, then a more persistent insecticide should be used. Grasshoppers and cutworms can also be controlled by poison-baiting.

(6) Precautionary operations No. 1 to 4, if carried out properly on a large-scale co-operative basis, should not allow the borer population to build up beyond tolerable limits. If, however, due to some reasons these precautionary measures are not practicable and yet intensive chemical operations are feasible, then a suitable persistent insecticide should be applied in such a way as to poison the just-hatched larvae of the borers during the few minutes when they crawl on the surface of the plant before boring into the plant tissue. For this purpose, insecticidal application preferably as sprays or granules, should be carried out just before the peak period of hatching. *The peak period can be determined by means of a biometer for the species.* The chemical control should be integrated with other methods of control.

CHAPTER V

PESTS OF SUGARCANE

SUGARCANE is a cash crop which is closely related to cereal crops, specially millets. Hence, the entomological problems facing sugarcane crop husbandry are akin to those of millets. But from the viewpoint of pest control and its economics, two major differences are to be kept in mind : (1) From the point of view of economic return, sugarcane and millets are probably at antipoles; sugarcane cultivation can afford much costlier control measures against pests and diseases than millet cultivation. (2) The millet is propagated by seed-grain which is also stored both for food and sowing purposes, whereas sugarcane is propagated vegetatively by planting setts cut out from the stem of the plant. Though these setts contain the main food product—sugar, they are not kept in storage. The entomological implication of this difference is that millets suffer from insect damage both in the field and in storage, while sugarcane presents the entomological problem only in the field. Of course in the field stage the pest problems of sugarcane are obviously more serious than those of the millet crop. Hence on the whole, it will require quite a careful experimentation to assess the relative position of the two with respect to the pest problems.

The lower, mainly, the underground portion of the sugarcane plant, is damaged by (1) termites specially in the early stages when germination is considerably reduced and in areas where irrigation facilities are poor, and (2) the lepidopterous root borers. Also sometimes, other soil insects like the white grub do some amount of damage. The middle portion of the plant is subject to attack by more than half a dozen lepidopterous stem-borers and the upper portion is often infested by another lepidopterous top-borer. Besides these, a very threatening pest of sugarcane is the *Pyrilla* bug. Mites and other insect pests like white flies, mealy bugs, etc. are generally sporadic and comparatively less important. In all, more than 20 species of pests attack the sugarcane crop in India. Out of

these, the following four will be described *viz.* the top-Borer, the stem-Borer, the root-Borer and Pyrilla; termites have already been described earlier.

THE TOP-BORER

[*Tryporyza nivella* (Fabricius)]

(*Plate XI*)

As the name indicates the attack of this pest is always confined to the top portion of the sugarcane shoot; the growing point is damaged seriously resulting in the drying-up of the central whorl of unfurled leaf which forms the characteristic dead-heart. The destruction of the growing point of a grown-up shoot also results in the abnormal activation of the side-buds just below the growing point and they produce a bunch of small side-shoots, leading to the appearance of the symptom generally referred to as *bunchy top*. This bunchy top symptom is not produced when very young seedlings are attacked because at that time the very short stem portion is still below ground level and the destruction of the growing point results in somewhat early production of tillers; at this stage there is actually no top to become bunchy.

The adult of this pest is a medium-sized moth (wing span a little more than 3 cm) which has a very distinctive uniformly creamy-white colour and the grandeur of this characteristic white brilliance is further enhanced in the case of the female by its anal end which is deep-red in colour and is covered with a tuft of buff-coloured hair. These moths are nocturnal in their activity but they do not hide in the day and can be seen resting on sugarcane and also on other plants in the vicinity. They lay eggs in very prominent masses which are covered with buff coloured hair from the anal tuft of the mother and which are quite conspicuous even from a distance against the background provided by the green leaves. The eggs hatch generally after a period of one week. The first stage larvae bore into the midrib of sugarcane leaves and begin their journey down the midrib and towards the base of the leaf. These tunnels within midribs appear like white streaks and these streaks constitute quite dependable symptoms, besides bunchy top, to distinguish the attack

Plate IX

A. Different stages of the *jowar* stem borer (*Chilo Partellus* Swinhoe)
(Courtesy Dr. W.R. Young, Entomologist Rockfeller Foundation New Delhi.)

B. Chemical control for *jowar* pests, with special reference to the shoot fly and stem borer—untreated (*left*) and treated (*right*).
(Courtesy Dr. M.G.Jotwani, Millet Entomologist I.A.R.I New Delhi)

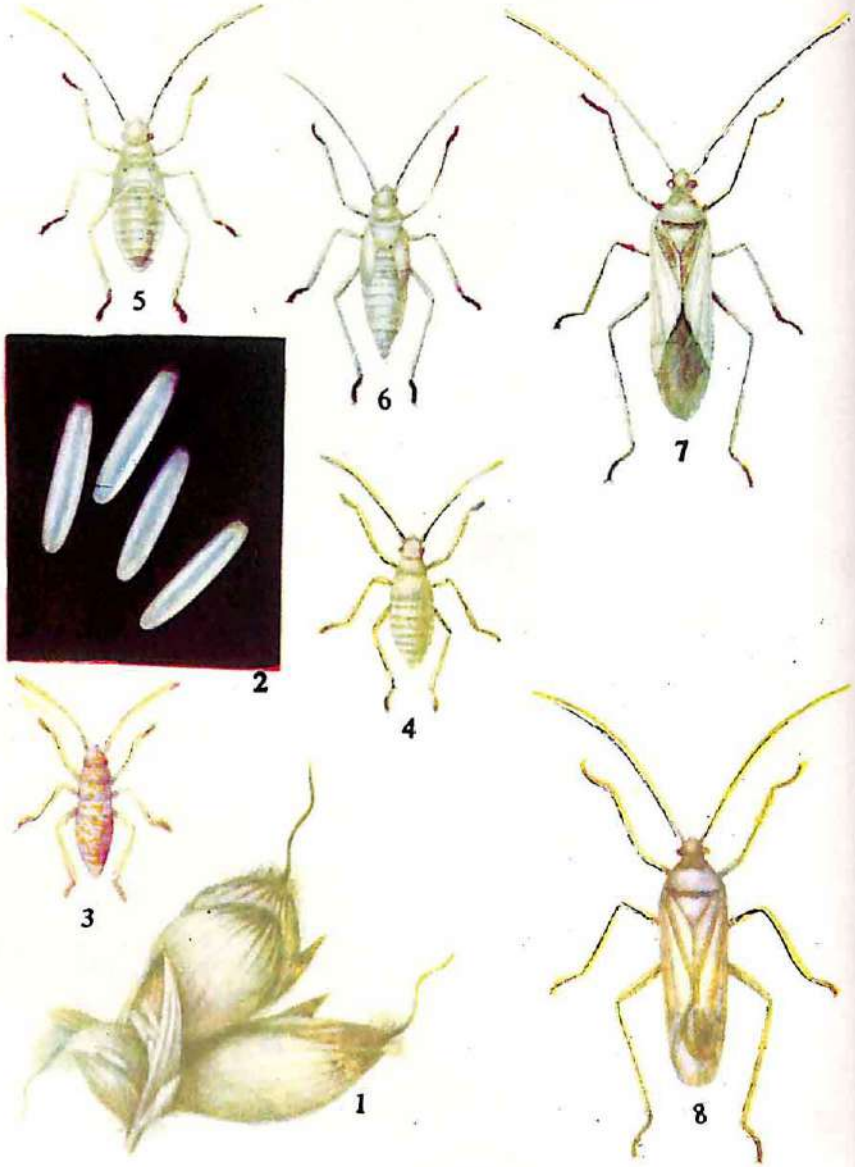


Plate X—EARHEAD BUG

1. Egg *in situ* 2. Eggs 3—6. Nymphal stages 7 & 8. Male and female adults.

(*Pusa Bulletin*, No. 58)

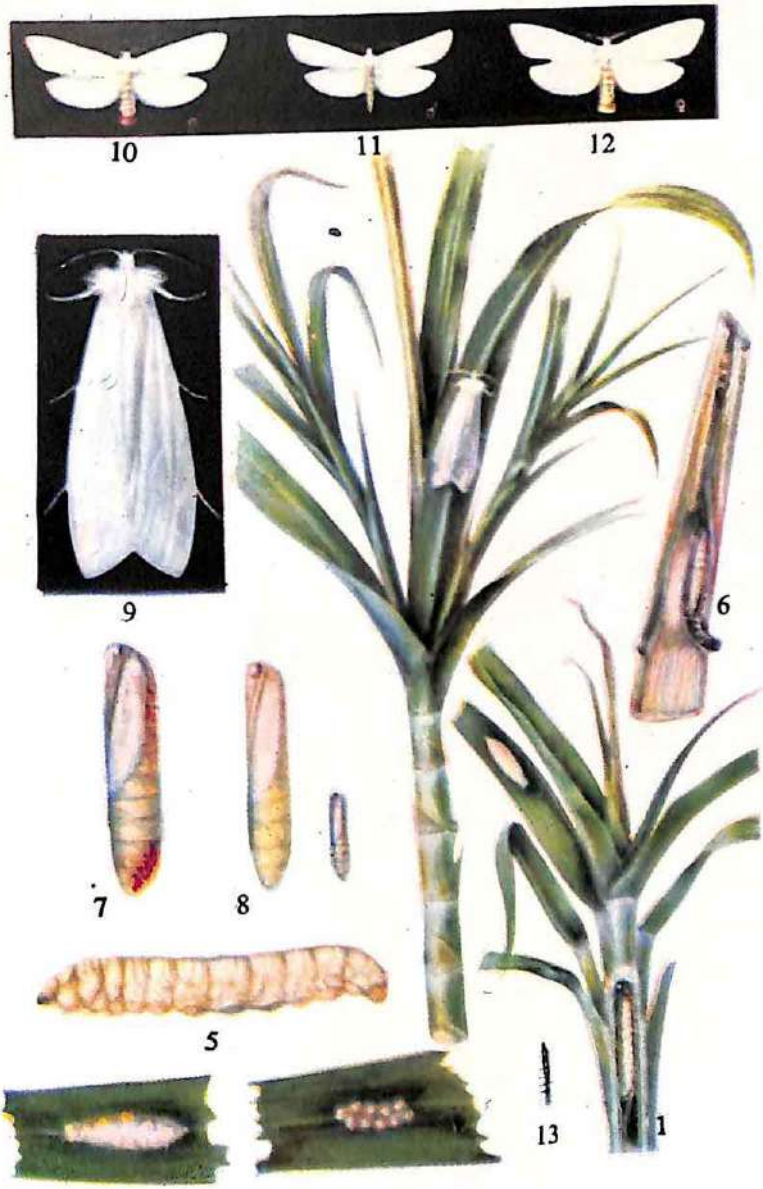


Plate XI—Top Borer

1. Attacked shoot of sugarcane showing larva inside; note 'dead-heart' and egg-mass on leaf 2. Attacked shoot of sugarcane with 'dead-heart' and side shoots thrown out. On leaf is a moth in resting position 3. Egg-mass with covering hairs 4. Egg-mass with covering hairs removed 5. Full-grown larva 6. Pupa in stem; note hole of exit closed by silken barriers, prepared for escape of moth 7. Pupa of female 8. Pupa of male 9. Moth in natural resting position 10. Moth, female, form with reddish tuft 11. Moth, male 12. Moth, female, form with yellow anal tuft 13. Newly-hatched larva.

(*Proc. 3rd Ent. Meeting*, p. 381)

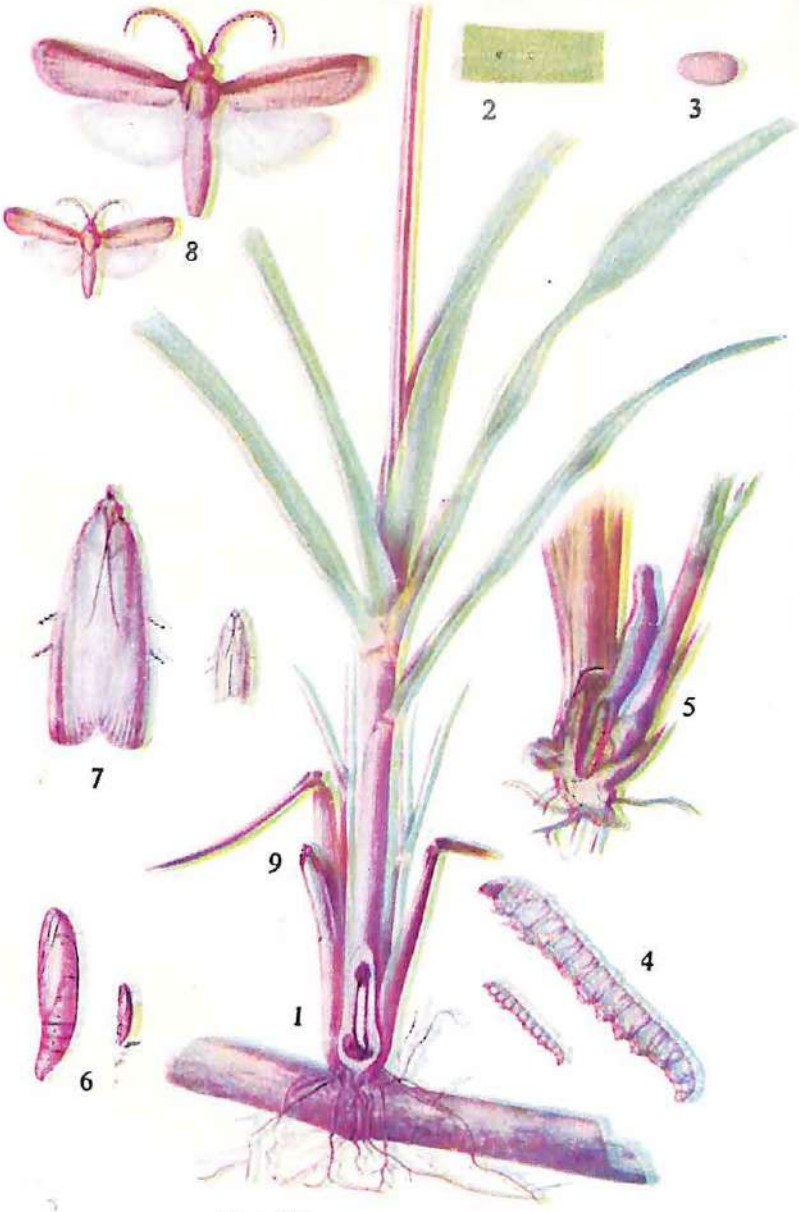


Plate XII—Root-Borer

1. Young cane shoot cut open to show attack by larva; note 'dead heart' 2. Eggs as laid on a leaf 3. Egg 4. Full-grown larva 5. Cane plant cut open to show pupa; note cocoon with gallery prepared for moth's exist 6. Pupa 7. Female moth in resting position 8. Male moth.

(Proc. 3rd Ent. Meeting, p. 379)

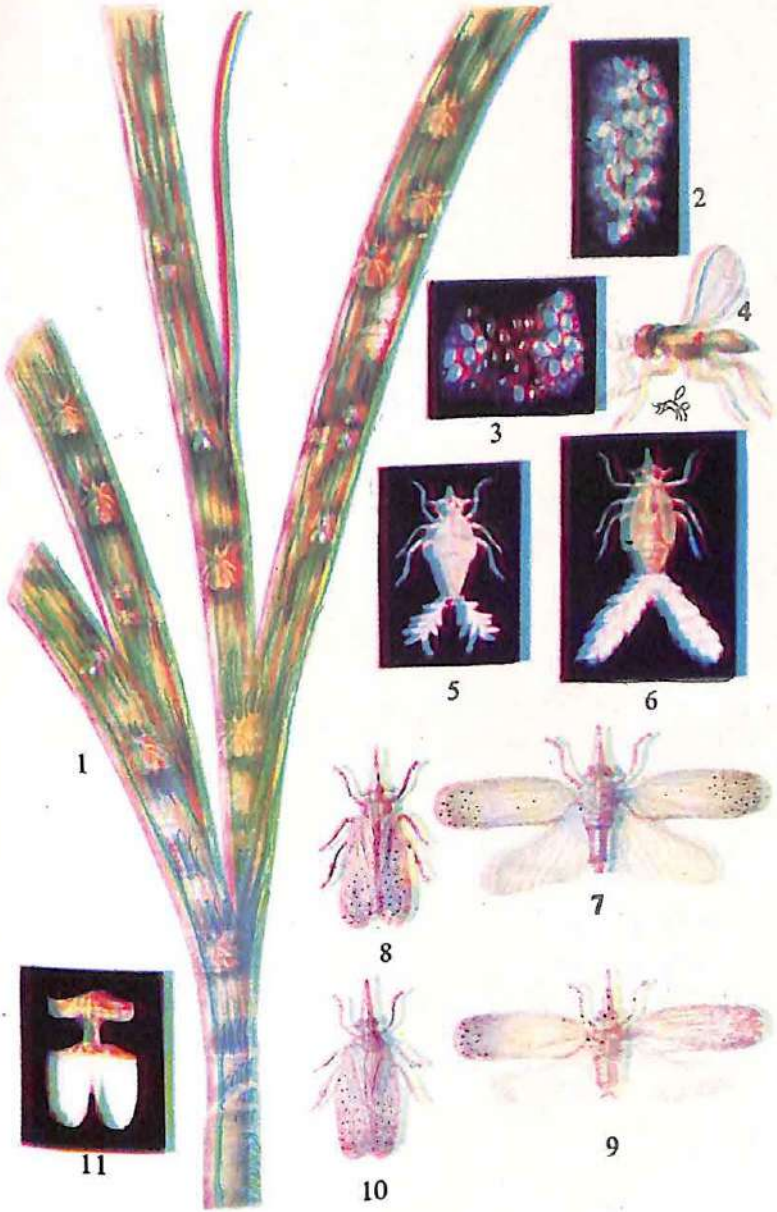


Plate XIII—PYRILLA

1. Sugarcane twig covered with various stages of Pyrilla 2. Eggs 3. Eggs.some of which are parasitized 4. Egg parasite 5 & 6 Nymphal stages 8 & 10. Male and female adults respectively in resting posture 7 & 9. Male and female adults, (set) 11. Anal tuft of female adult.

[*Mem. Deppt. Agri. India, Ent. Ser.*, V (2), Plate 10]

Plate XIV—Gram Pod-Borer
(*Heliothis obsoleta*, Fb.)

1. Egg laid on tur-pod 2 & 5. Caterpillars on gram plant, also eating into pods 6. Pupa in underground cell 7. Moth in repose 8. Moth with wings stretched.

(*Proc. 2nd Ent. Meeting*, p. 49)

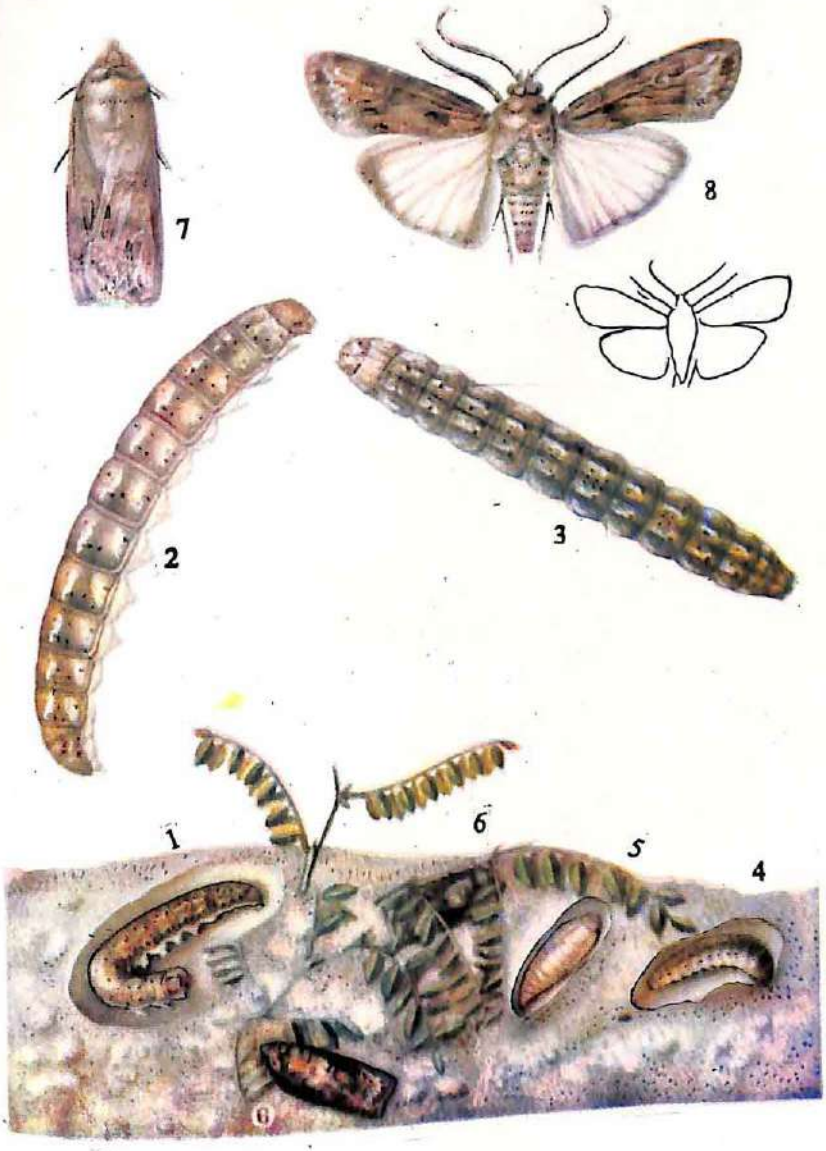


Plate XV—CUTWORM

Agrotis ipsilon

1. Caterpillar hiding during daytime under soil near the base of cut plants (earth removed to expose caterpillar) 2 & 3. Larvae 4. Larva pupating in pupal chamber 5. Pupa 6. Moths resting during daytime 7 & 8. Moths in resting and flying attitude

(*Proc. 2nd Ent. Meeting*, p. 48)

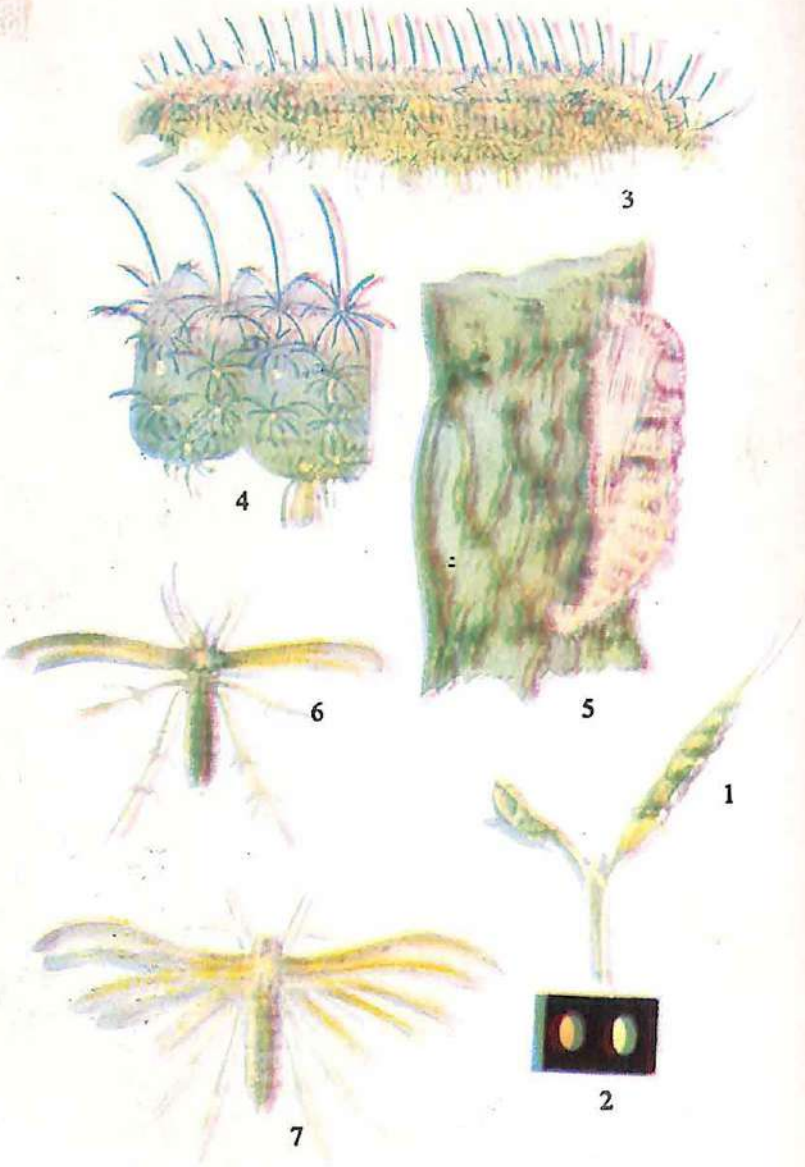


Plate XVI—TUR PLUME MOTH

1. Eggs on pod pigeon pea. 2. Eggs 3. Larva 4. Second and third abdominal segments of larva 5. Pupa on pod of pigeon pea. 6. Moth, in normal resting position 7. Moth (set).

(*Indian Insect Life*, p. 528)

of the top-borer from that of other borers to be described later. Several larvae enter the midribs of several leaves but only one reaches the growing point at the base of the leaf. The larva enters the growing point which gets destroyed as pointed out above and the larva finds itself in an environment of plenty and safety. In the course of four or five weeks, the larva becomes a full-grown fleshy caterpillar which is about 3 cm in length and creamy-yellow in colour. During the whole of this period, the larva does not descend below 25 to 30 cm from the top of the stem and pupation also takes place within this top portion. In the normal season the pupal period generally lasts for a week or ten days and thereafter the moth emerges through an exit hole perpared in the stem by the larva before pupation. Thus, there are several generations during one crop season till winter sets in and the full-grown larvae enter hibernation. The larvae of this generation of the year pupate only when the weather warms up during the following spring.

From the foregoing account, it should be clear that the damage casued by the top-borer should largely depend on the age of the plant at which the attack comes. The attack at the early stage of the plant may kill the seedlings, a little later it may lead to tillering, and after a sizeable portion of the stem has been formed, the attack means that the cane remains stunted with a bunchy top; the attack may be somewhat less harmful at a much later stage when the normal growth has been completed.

About a dozen species of insect parasites have been reported to exert varying degrees of check on the population build-up of the top-borer; but despite these, the pest continues to be a very serious bottleneck in increasing sugarcane production in the country.

The stages in the life-cycle at which this pest can be controlled are, firstly, the egg-stage at which the prominent egg-masses can be collected and destroyed and, secondly, the dead-heart and bunchy-top stages which also can be rogued out along with the pest larva. Besides these mechanical controls, the pest can also be checked by treating the crop with a good persistent contact insecticide which may kill the moths before they lay eggs and which may also kill the first stage larvae before they enter the plant tissue. A very careful timing of these insecticidal treatments is necessary to ensure success.

THE STEM-BORER

There are more than half a dozen species of moths the larvae of which bore into the middle portion of the sugarcane stem and which are collectively referred to as stem-borers. In grown-up shoots they generally do not go up to the region which is generally attacked by the top-borer described already and also they do not go down to the region generally infested by the root-borer. This differentiation, however, is not practicable in the seedlings and early stages of the crop when the stem formation is too meagre for the various species of borers to exhibit their preferences for the different regions of the sugarcane stem. The general habits and the pattern of life-history are practically similar in the different kinds of stem-borers, although there are significant differences in the details of their idiosyncrasies. Out of these, it is proposed to describe below the species which earlier used to be referred to by its scientific name *Argyria sticticraspis* but which is now called *Chilo infuscatellus* Snellen. Unlike several other stem-borers, this species is distributed throughout the sugarcane regions of India; and outside India its distribution extends to Burma, Indonesia, Taiwan the Philippines, etc. It attacks a number of other plants of the family of grasses but its attack in India is most serious in the case of sugarcane crop.

The adult stage is a medium-sized moth with a wing-span of 3 cm and the colour varying between different shades of straw hue; the hind-wings are somewhat lighter in appearance and texture. It is attracted to the crop which is still quite young. It is nocturnal in habit and spends the day resting on the underside of dried leaves against the background of which it is not at all conspicuous. It lays scale-like eggs which are arranged overlapping one another in two or three short adjacent lines each of about a dozen eggs and generally on the underside of sugarcane leaf. The eggs hatch in about a week's time and the larvae at first feed on the leaf epidermis and then bore into the stem portion. In very young shoots or tillers with very meagre stem formation, the feeding and boring activities of the larvae destory both the growing point and the base of the central whorl and the characteristic dead-heart is formed. This does not occur a little later in the season when stem formation has progressed well because the larva can then continue to tun-

nel the stem without destroying either the growing point or the leaf base without creating any prominent external symptom. The larvae are dull-white in colour with a number of brownish-red longitudinal stripes on the back and at the full-grown stage they are about 2.5 cm in length. The significant characteristic habit of the larvae is that unlike the top-borer, they bore in and bore out a number of times either in the same stalk or in the neighbouring ones. The larval period lasts about three weeks after which the larvae pupate in the tunnel within the sugarcane stalk where they had been feeding before. The pupal period lasts generally a little more than a week after which the moth emerges from the exit hole prepared by the larva before pupation. It completes several generations between spring and fall and the winter is passed in the hibernating larval stage.

The natural enemies of this species in India include two species of insect parasites attacking the egg-stage, about half a dozen species attacking the larval stage and at least one species attacking the pupal stage. Despite these natural checks, the pest continues to be quite serious.

From the foregoing account, it will be seen that the rationale of the control measures against this pest lies in the feasibility of removing, in the early stages of the crop, the affected shoots showing dead-hearts, making sure that the pest larva is also removed and destroyed. Also in the early stages of the crop, a light earthing-up may make the stem portion inaccessible to the larvae. These measures are of no avail once stems of sizeable length have been formed. The chemical control can be directed either against the moths which should be killed before they are able to lay eggs or against the first stage of larvae which should pick up lethal dose of insecticide before they enter the plant tissue. This means that chemical control operations have to be precisely timed with the help of a biometer. However, residual sprays can be somewhat more successful in the case of this species where the larvae bore-in and bore-out than in the case of borers like the top-borer which do not come out of the stalk in the larval stage.

THE ROOT-BORER

(*Emmalocera depresella* Swinhoe)

(*Plate XII*)

This pest has been called by different names since the late nineteenth century when it first attracted scientific interest. However, its present name is continuing since 1918. Although its seriousness as a pest of sugarcane varies from place to place, it has been recorded from different sugarcane regions of India and has also been reported from Indonesia. It is essentially a soil pest and attacks the underground portion of the sugarcane stem. Hence, it is commonly called the root-borer although it does not attack the roots which in sugarcane are generally too thin to be bored by this species. It also attacks a number of other graminaceous plants.

In the adult stage, it is a straw-coloured moth with a wingspan of about 25 mm. Like other moths it is nocturnal in habit and flies about and lays eggs during the night. However, unlike the other two moth pests of sugarcane described earlier, this moth generally lays eggs not in masses but singly under field conditions. Also, the larvae hatching out in about a week's time differ very significantly from the larvae of other two moth pests; these larvae crawl down the plant and enter the soil through cracks and crevices generally along the plant surface and bore into the plant tissue a few centimetres below the soil surface. There is heavy mortality during this journey which nevertheless may last for less than 15 minutes. However, like other moth larvae this also causes a dead-heart in the early stages only and not in the grown-up crop when the girth of the internodes becomes thick enough for the larvae to feed in the middle without cutting the food supply of the leaves. The larva is fleshy in texture, wrinkled in surface and creamy-white in colour. They have also a tendency to come out from the node into which they once entered and bore in again either in the same or in adjoining shoots. The larval period during the crop season lasts for four or five weeks, but in the case of the hibernating larval stage, it may last for 200 days or more. Pupation takes place within the cane stem but generally below ground level; the

larva, however, before pupating makes a silken tunnel within the cane from the place of its winter bed up to ground level and makes an exit hole there for the moth to emerge after the pupal period of 1½ to 2 weeks is over. There are several generations from early spring to late fall.

As regards saving the sugarcane crop from the attack of the root-borer, it should be more rational to treat this species as a soil pest which it actually is rather than like the stem-borer and the top-borer. Effort should be made to exploit the larval habit of entering the soil and of migrating from one shoot to another below the soil surface by treating the soil with a persistent soil insecticide like aldrin, chlordane or heptachlor so that the pest may pick up the lethal dose during its larval movement below the soil surface. Of course, this rational approach has not yet received a sufficient practical trial. The other possible ways of control are, as in the case of other borers, removal of plants with dead-hearts making sure that the larva is also removed and destroyed and chemical treatment of the crop against the adult stage which should be killed before laying eggs in the crop. Cultural control like discouraging ratooning, removal of stubbles, etc. also hold out promise as part of a large-scale campaign.

PYRILLA LEAF-HOPPER

(*Pyrilla perpusilla* Walker)

(*Plate XI*

This is a straw-coloured Fulgorid bug with a characteristic forward projection from the head into a prominent sharply-pointed beak-like snout. It is about 10 mm in length. There has been some confusion in the past about the number of species of *Pyrilla* present in India but now it is generally considered that there is only one species in the country. Its serious epidemic is rather sporadic in occurrence but it is found in practically all the sugarcane-growing areas of India and Sri Lanka. The serious epidemics of *Pyrilla* on record are those of 1938 in U.P. and 1938 and 1941 in the Deccan. It is a major pest of sugarcane but it has been reported to damage other crops also, particularly in the neighbourhood of

sugarcane fields. There are several reports and observations indicating that this insect has assumed the status of serious pest on pearl millet (*bajra*), sorghum (*jowar*) and maize.

Like bugs in general, this pest sucks the plant sap by puncturing the leaf again and again at short intervals and when hundreds or even thousands of these insects are busy draining out the sap from each sugarcane leaf, one can easily understand the damage caused to the plant. Practically all the stages of the insect, right from the time the tiny nymph hatches out from the egg till the natural death of the long-lived adult, continue to inflict similar injury to the plant. Besides causing direct physical injury and considerable drain on the vital fluid of the plant-system, these insects secrete a kind of sweet fluid generally referred to as honeydew. The leaf surface gets covered with this material which attracts a number of other insects and encourages the growth of a kind of sooty mould. The result is that the whole crop gives a blackish unhealthy appearance, the utilization of the sunlight during photosynthesis is hindered and considerable decrease results not only in the yield of sugarcane per hectare but also in the sugar recovery and quality of sugar recovered.

The adult insects have a comparatively long life extending sometimes up to even six months or more. In spring they lay eggs on young sugarcane leaves in fairly large masses which are covered by a kind of white filamentous material. These egg-masses are quite conspicuous against the green leafy background. Later, during the fall season the eggs are laid on the inner side of the dried leaf sheaths which provide some safety both against biotic and climatic inclemencies. Each female lays many egg-masses, the total number of eggs reaching several hundreds in each case. During normal summer and monsoon periods, the nymphs hatch out in a week to 10 days but this time can get lengthened to six weeks or more when temperature comes down.

The newly-hatched nymphs are waxy and white in colour and their special characteristic is the possession of two waxy and white brush-like filamentous projections from the hind end of their body. These nymphs continue to be only hopping creatures till after a number of moults they develop into adult forms with well developed wings and flying capabilities. This may take from one

to five months or so. There are four to five generations in a year and generally the pest overwinters as nymph which develops into adult in early spring.

There is quite an impressive list of enemies of this pest which appear in succession and exert apparently a very effective check on its population build-up. Five species of insect parasites and one insect predator attack at times up to 90 per cent of the eggs, one lepidopterous predator and a peculiar internal parasite called stylops kill and decapacitate the nymphal and adult stages. Also, there is a fungal parasite which at times creates an epizootic on the *Pyrilla* population.

The weakest point in the life-history at which this pest can be effectively checked by mechanical means is the egg stage. The new crop in spring is first attacked only by a small population of adults and this small population lays comparatively a very small number of large egg-masses which are very conspicuous against the background of the leaf. Hence, the best policy should be to get these egg-masses clipped and destroyed at this early stage. If this mechanical operation has not been effectively carried out, then the crop should be treated with a good persistent contact insecticide which should continue to kill both the nymphs hatching within the crop and adults invading from outside. Later on, during the fall if a large number of egg-masses have been laid within the dry leaf sheaths, then the stripping of these dried leaves should be undertaken on a mass scale. In any of these control measures, the good work being done by parasites and predators should be kept in view.

Control Schedule

The main characteristics of some of the serious pests which can be kept in view in devising their control measures are :

(*a*) The top-borer and *Pyrilla* lay their eggs in large prominent masses which can be easily located even from a distance against the green background of the leaf surface. This characteristic makes these pests quite suitable for the adoption of mechanical control measures, i.e. collection and destruction of egg-masses. This is quite a feasible proposition under Indian conditions where

batches of school boys and girls can easily clean up large areas. Supervision is also easy for such campaigns because if the collection of egg-masses has not been carried out properly, the same can be detected by visual survey.

(*b*) All the three types of borers, viz., the top-borer, the stem-borer and the root-borer cause characteristic dead-hearts in the early season of the crop and the collection of such affected shoots along with the insects associated therewith can be combined with the campaign mentioned under (*a*) above. Top-borer attack can be easily detected during all stages of the crop.

(*c*) Both *Pyrilla* and borer pests are often heavily parasitised in their different stages. Hence, the control schedule should keep this point in view.

(*d*) All the different types of borers lay their eggs on the plant surface and their just-hatched larvae crawl on the surface for a few minutes before getting into the tissues and thus out of reach of the insecticidal chemicals. Hence, the different operations of the control schedule have to be precisely timed.

On the basis of the above mentioned considerations, one should attempt a control schedule on the following lines :

(1) The sugarcane planters should be made fully conscious of the fact that sugarcane is a graminaceous crop and as such most of the other wild graminaceous plants growing in the vicinity and on the bunds serve as alternate food plants for sugarcane pests. Hence, keeping the area clean of these alternate food plants including the stubbles of the previous season's crop on as large a scale as possible is a necessary prerequisite for successful sugarcane cultivation. This is a precautionary measure which should not wait for the appearance of any pest or even for sowing of the crop.

(2) The next precautionary measure to be adopted at the time of sowing is against termite and root-borer attack, specially in areas where these troubles cause a headache year after year. This precaution consists of chemical treatment of the furrows in which these setts are to be sown, so that termites and young root-borer larvae trying to approach the sugarcane plant may get a lethal dose of insecticide.

(3) If the termite attack is assuming seriousness despite the above-mentioned precaution or because that precaution has not

been adopted, then the charging of irrigation water with a repellent or a suitable insecticide has to be resorted to as a curative measure. This operation need not form a regular item of the control schedule and has to be resorted to as and when necessary.

(4) Full preparation and all arrangements should be made to organize campaigns on as large a scale as possible to nip in the bud the attack of borers and *Pyrilla* as soon as the egg-masses and dead-hearts begin to appear in the young crop. These should be collected and destroyed by a number of workers specially employed for the purpose. This step should be regarded as the most crucial operation for success against sugarcane pests. As this operation involves control measures against a number of species, one should be sure that some pest or other is bound to make its appearance every year, depending on the experience of the past years. Hence, no chances should be taken so far as this mechanical control operation is concerned. This round of operations should form one of the routine items of sugarcane cultivation and should be continued as long as these symptoms exist.

(5) Both *Pyrilla* and top-borer egg-masses are at times heavily parasitised. Therefore, arrangement should be made to conserve the parasites by keeping the egg-masses in wire-gauze cages from which only the minute parasites can fly out but the *Pyrilla* nymphs and borer larvae are either trapped in the cage or made to fall into a pail of kerosenized water. The extention workers should take special care to train the farmers in this respect.

(6) If the foregoing operation has been carried out effectively and on a sufficiently large scale so as not to upset its beneficial effect by migration of insect pests from neighbouring areas, then the problem should be significantly reduced in magnitude in the main part of the crop season. All the same, the farmer has to keep a vigil and adopt control measures as and when necessary. It may be necessary to get the egg-masses of the top-borer and *Pyrilla* and the tillers affected by borers collected and destroyed in the main season also. But generally in the main season, chemical control operations will have to be resorted to. *Pyrilla* can be controlled by a number of contact insecticides but it should be advisable to time these operations with the help of a biometer in such a way as to coincide with the peak of the hatching of the

borer eggs so that the same operation can poison the first stage larvae also before they bore into the cane. With this end in view, it will be better to select a contact insecticide with a suitable period of persistence and thereafter efforts should be made to integrate this chemical control with biological control. In case mite infestation also makes its appearance, it will be better to choose a chemical which will control both insects and mites instead of using a specific chemical like sulphur which will kill only the mites.

In the foregoing schedule of control operations against sugarcane pests, we have not tried to go into details like the chemicals to be recommended, the concentration to be used, etc. It is firstly because the data available have not yet been subjected to an overall coordination which is necessary before a coordinated anti-pest control schedule for a crop can be formulated and, secondly, because they are based on isolated experiments for each individual pest. These isolated experiments are very necessary for affording basic information but finally overall relative effectiveness of each treatment and each operation has to be worked out and tested on a large scale in a way as would afford dependable information on the economics of the operation on the one hand and how suitably it can be fitted into the general existing schedule of the crop husbandry on the other.

CHAPTER VI

PESTS OF PULSE CROPS

THE IMPORTANCE of pulses as the main available protein source for vegetarians in India needs no emphasis. From the viewpoint of pest control, however, the main characteristic of these crops is that several of them can be raised for more than one purpose : some may be meant just for green-manuring for enriching the soil with nitrogen fixed from the atmosphere; others may be there for fodder, some may be raised for green pods used as vegetables and still others may be for harvesting in the normal course for grain. Sometimes the same crop may be used for more than one of these purposes. For example, the tender shoots from several of the pulse crops are cooked as vegetable (*saag*) for human consumption. Sometimes these shoots are consumed by man right in the field even without washing. Due to this multipurpose nature of pulse crops, extreme care is necessary to guard against health hazards due to pesticide residues.

Although there are as many as 150 species of insects attacking 10 different crops of pulses, farmers are likely to be most often bothered mainly by cutworms and other caterpillar pests, aphids and agromyzid fly maggots acting as leaf-miners, stem-borers and pod-borers. Hence, it is necessary to describe some examples of each of these groups.

THE GRAM POD-BORER

(*Heliothis armigera* Hübner)

(Plate XIV)

Different species of *Heliothis* are universally distributed and polyphagous in feeding habits. In the United States of America, it is a serious pest of cotton and is known as Amrican cotton bollworm. In India, it was of minor importance on cotton till recently. Now there are several reports about its causing serious damage to new high yielding cotton hybrids, especially in Maharashtra and southern States. It also appears sporadically as a

serious pest on earheads of sorghum (*jowar*). It is a serious pest of *rabi* crops, particularly red gram and Bengal gram. This explains its common name of the gram pod-borer in India.

In the adult stage it is a typical stoutly built Noctuid moth with a wing span of 30 to 40 mm and colour varying from olive-grey to reddish-brown. The forewing has a dark speck and a dark area near the outer margin; the hind one has a dark outer border. It lays eggs singly on the tender parts of its food plants. The eggs are spherical, sculptured and with greenish shine. The egg-period lasts from a few days to more than a week, depending on the temperature. The young larva begins to feed on the tender portions of the leaves and shoots. As the larva grows and as the pod formation takes place in the crop, it is often found feeding on the developing grains after cutting a hole in the pod and thrusting its head therein. Both the colour and the size of the larvae vary within wide limits, the full-grown caterpillar reaching a length of about 35 mm. The colour pattern consists of variable combinations of pale green and pale brown with longitudinal stripes along the sides. The larval period lasts about two weeks after which the larva enters the soil, makes there an earthen cocoon and pupates. The pupa is dark brown in colour and about 12 mm in length. The moth emerges a week after pupation. There may be as many as eight generations in a single year.

The control of this pest was quite difficult in the past. The inorganic stomach poisons available in the past were not quite effective because the grown-up larvae would mostly feed on the developing grains inside the pod which is out of reach of the stomach poison applied on the outer surface. Now, however, there are persistent insecticides working both as contact poison and as stomach poison. Therefore, the control problem has become easy; except that due care has to be taken to properly time the insecticidal application in different regions.

CUTWORMS
(*Agrotis* Spp.)
(*Plate XV*)

Winter is generally a lean season for insect pest activity. The cutworms, belong to that comparatively small group of pests, the

destructive activity of which is more marked in *rabi* crops. They are known as cutworms because they cut and fell to the ground either the whole plants of low crops like gram or their twigs. They are also referred to as surface caterpillars because their activities are mostly confined to a few centimetres of the surface layer of the soil. Their collective names apply to a number of species of Noctuid moths, particularly those belonging to the genera *Agrotis* and *Euxoa*. Amongst them the species *Agrotis ipsilon* Hufnagel, is the commonest and most widely distributed. It is also sometimes called the greasy cutworm because of the greasy appearance of the full-grown caterpillar. The following account is based mostly on the studies carried out on this species although it also applies to other species in respect of some general characters.

The adult stage is a dark brown moth with a reddish tinge, measuring about 25 mm longitudinally and with a 40 to 50 mm wing-span. During the day these moths remain in hiding under the leaves, in cracks and crevices and when touched they sometimes feign death; when further disturbed they shoot out to find some other dark corner. They are, however, often seen flying about from the time it is dusk till it is quite dark. Thereafter, they start ovi-position. They lay eggs mostly on the underside of the leaves which are nearer to ground level. The eggs are laid in clusters of upto about 30 eggs, although each moth can lay thousands of eggs. Each egg is round, dome-shaped and sculptured with radiating ribs of a greenish-white tinge. The hatching takes place within two to six days or more and the young larvae begin to feed on their eggsheel as their first meal and fall to the ground at the slightest disturbance and hide under fallen leaves. There they feed on the epidermis of fallen leaves or the green leaves touching the ground. When about half-grown, the larvae develop the habit of burying themselves during the day under loose soil. They are generally nocturnal in behaviour but, when in large swarms, they come out during the day also and hide only during the hottest part of the day. During the night they come out, cut a leaf or shoot and partially drag the same into the soil. This partially buried shoot is almost the sure index of the place where the larva is hiding. Also sometimes, the larvae cut the whole plant at the base, below or just above the surface level. Thus, the destructive peculiarity of the pest

is that it destroys much more than what it actually eats. The full-grown caterpillar is about 40 to 45 mm in length, plump, rather smooth and flattened in look and dull grey-brown in colour. The gait of the first stage larva is peculiar in that it walks with some kind of hump like that of the semiloopers; this peculiarity disappears after the first moult. They have the habit of coiling up at the slightest disturbance. After four or five weeks of larval life, the cutworm enters the soil much deeper than during its usual activity, constructs an earthen chamber, the sides of which are made smooth and hard by an exudation from the mouth; the pupation takes place in the chamber. The pupa is a red-brown chrysalis about 20 mm in length. The pupal stage lasts for 10 to 30 days or more, depending on the climate and thereafter the moth emerges out to start a new generation.

The activity of this pest, particularly in the northern belt of Bihar, U.P. and Bengal where it is very serious, shows up sometimes during October and the attack on the *rabi* crop becomes most marked during the December-January period. It is polyphagous but its preference is highly marked for gram, tobacco and potato. They are highly cannibalistic; at times the larva bites even its own body. The attack assumes rather epidemic proportions in areas which have been flooded during the previous monsoon. They appear year after year in areas liable to annual inundation. These peculiarities have remained unexplained so far. Its greater abundance in the *rabi* season is not because unlike other insects the winter temperature is more favourable; studies have shown that like other insects the development of this pest is also quicker in summer than in winter. All the same, its attack is more severe in winter. One view is that the moths migrate to the hills in summer. However, it is also not unlikely that its abundance in winter may be due to its predators being in hibernation during the winter season, and during summer it may be much more subjected to predation. It is likely that plump larvae may be attracting the attention of predators much more than other smaller insects. The same line of thought may also explain the epidemic in areas which are subjected to annual flooding because the flood might be causing wholesale destruction of predators in the flooded areas. The moth is reported to be attracted by the smell of wet soil when water is

receding. Some studies have been carried out on the effect of flooding on the various stages of the cutworm itself. The eggs can stand submergence for five days or so; the small larvae coil up and float on the surface and may be carried away to the safety of the dry soil or to sure destruction when submerged. The older larvae, however, get paralysed after struggling with water for 15 minutes or more; they may revive if they have not been in water for too long. The pupae can tolerate submergence for about eight hours but those caught in watery mud get killed. Both larvae and pupae are very susceptible to direct sun in which they soon get shrivelled up.

In the past, large-scale control of the pest was considered to be quite difficult. Hand-picking has been suggested as a practical control measure; this is possible only in the case of old larvae, the presence of which can be detected by the plants felled by them. They are also attracted to poisoned baits. During recent years, insecticidal dusting has been recommended. However, the most rational approach is to keep the soil surface well treated with a good persistent soil insecticide so that as soon as the just-hatched larvae fall to the ground, they may begin to pick up the insecticidal dose.

THE PLUME MOTH CATERPILLAR

(*Exelastis atomosa* Walsingham)

(*Plate XVI*)

As a pest this insect is fairly specific to red gram (*Arhar*) to which it at times causes serious injury. However, it has a number of alternate host plants as well. It occurs in most of the regions of India growing red gram. It is also reported from places outside India like Natal, New Guinea, etc. Sometimes it occurs in the company of another very similar species of plume moth (*Sphenarches caffer* Zell.) which unlike this pest generally feeds on cucurbitaceous plants as well. The caterpillar cuts a hole in the red gram pod opposite to a seed developing inside and then inserts its head in that hole and feeds from outside on the developing seed. When one seed is consumed; the larva leaves that hole and cuts another opposite to another developing seed. Thus, it damages quite a high percentage of developing seeds which cannot be replaced and are thus totally lost.

The adult is a small (about 7 mm in length and 15 mm wing-span) beautiful greenish-brown plume like moth, as its name indicates. It belongs to the family Pterophoridae containing many species of plume moths. The wings, each of which consists of several longitudinal fringe-like filamentous lobes, constitute the plume and they are gracefully held together on either side at right angles to the body of the moth when it is at rest. It is found flying at dusk and it rests during the day on the lower surface of the leaves and at other convenient places. It actually hangs from the plant by its anterior legs. It has comparatively quite a long life and can wait for a number of days for a suitable opportunity to lay eggs. These moths lay eggs singly on the tender pods of the food plant and these eggs hatch into tiny larvae about 1 mm in length within a few days. These young larvae at first scrap their food from the surface of the pod before they cut holes in it. At times they also bore into the unopened flower-buds and feed on the developing anthers. The larvae become full-grown within two to four weeks when they are about 7 mm long. The colour of the larva is a variable combination of green and brown tinge, so that it remains rather inconspicuous against almost a similar colour of the background of the pod on which it is developing. Another special peculiarity of the larva is that all over the body it has numerous rosettes of capitate spines and hair. It pupates on the pod or inside the hole of the pod damaged and the chrysalis also has spiny rosettes like the larvae; it is also cryptically coloured like the larva. The period lasts from three days to more than a week, depending on the prevailing temperature. There is no definite diapause in the life-history and the pest can feed all the year round, provided it finds suitable food plants and environment.

Since the larvae do not generally remain inside the pods, they can be easily poisoned by a strong persistent insecticide acting both as contact insecticide and as stomach poison. The crop should be treated as soon as pod-formation has taken place.

LEAF MINER AND OTHER AGROMYZID FLIES

(Plate XVII)

The bizarre patfern of tunnelling in leaves is a very common sight which always attracts the attention of even a casual obsesver. There

are several groups of insects the larvae of which mine the leaves; but among the pests of pulse crops, the leaf-miners of major importance belong to the family of Agromyzid flies. The family Agromyzidae includes many species of small or very small flies generally blackish grey or silvery in appearance. Their larvae are mostly typical leaf-miners or live in stems, pods, etc. of which the important examples are the pea leaf-miner (*Phytomyza atricornis* Meigen), the pea stem-borer (*Melanagromyza phaseoli* Coquillett) and the red gram pod-fly (*Agromyza obtusa* Mallas). All these pests follow a more or less similar pattern of life-history. For example, even the pea stem-borer starts its larval activity as leaf-miner and then follows its course through the leaf petiole into the stem. Also, the larva of the red gram pod-fly first mines zigzag tunnels under the epidermis of a developing seed and then bores into the interior. Further, although the common names of these pests suggest as if they are specific to a particular crop, they are actually polyphagous but due to the interaction of a number of factors, they generally cause serious damage to the crop after which they are named. Also most of these pests flourish best under a temperate climate and are widely distributed in various temperate regions of the world. In India their activity is largely confined to temperate seasons, i.e. fall, spring and also winter if it is not too cold; hence, they are mostly pests of *rabi* crops in this country.

It is proposed to describe the typical leaf-miner *Phytomyza atricornis* in some detail. This pest first attracted scientific attention in India in 1906 when it was described as cruciferous leaf-miner because it was first noted damaging the plants of the cabbage family. Besides India, it is very widespread in Europe, America, Russia, Australia, New Zealand, etc. where it is known under different common names according to the economic plant which it damages most. In India, it has been recorded from 29 different species of economic plants belonging to 13 families and the total for this species in the world reaches 90.

The adult is a very small fly, about 1.5 mm in length, and with a wing-span of less than 4 mm. An interesting fact about the habit of this fly is that it combines the action of feeding and ovi-position. It punctures the tender leaves with its ovipositor and then turns round to feed on the plant juice exuding from the puncture. Each

fly makes numerous such punctures on each leaf and these injured points develop into as many protuberances on the leaf. In some of these punctures, the fly oviposits; it lays one egg in each cavity. The male flies which have no ovipositor and therefore cannot puncture, wait in attendance near the females to lick the juice after the latter have left the place. Each female is capable of laying as many as 350 eggs in its whole life-span which may extend up to one month or so. The eggs are very small (about 0.3 mm in length) and oval-elongate in shape. They hatch within one and a half to five days into tiny maggots which begin to feed on the mesophyl of the leaf without damaging the two epidermal layers. This leads to the formation of zigzag galleries. Within 4 to 12 days, the larva develops to its full size of about 3 mm and then pupates within its last larval skin which hardens in due course; the pupa becomes reddish-brown or dark-brown in colour. The pupal period ranges from about 6 to 16 days after which the fly emerges to start another generation.

Under Delhi conditions, the fly makes its appearance in the crop sometimes during December or January and its activity increases from February onwards. From May onwards it becomes too hot and dry for this pest which completes four or five generations from February to April. The summer and part of autumn is apparently passed in the pupal stage under field conditions although if proper temperature and humidity are provided in the laboratory, the pest can continue its repeated generations throughout the year without any special period of physiological rest. As regards the natural enemies of this pest, an internal parasite of the larva has been recorded and studied.

The rationale of saving the crops from these pests consists of, firstly, the collection of the damaged portions of the plant when the attack just starts, so that the attack can be nipped in the bud and further multiplication checked. This is practicable because, to start with, the pest population is very moderate and the attacked portions can be easily spotted out. Even in the case of the pod-fly, the attacked red gram pods are quite distinctly twisted and deformed. The next approach should be the insecticidal treatment of the crop, choosing a contact poison with good persistence and penetrability. This will take care of, firstly, the flies which will get poiso-

ned while they are making numerous punctures on the leaf and, secondly, it will also kill the larvae of at least the leaf-miners because the epidermal covering of the tunnels made by the larvae does not offer enough protection particularly against contact insecticidal sprays. Poisoned baits against adults have also been recommended.

APHIDS

In popular terminology these insects have been referred to in the past as plant lice but now the scientific name aphid itself is quite common. It is advisable to defer the description of some general characteristics of this group for a later chapter dealing with mustard aphid which is by far the most serious crop pest of this group. Here it should suffice to mention that a black species of aphid called *Aphis craccivora* K. becomes at times quite serious on leguminous crops, particularly the pea crop. The infestation generally starts with a few individuals, each of which begins to reproduce rapidly, especially on the tender portions of plants. Very soon the population becomes so high that the infested plant gets completely covered. Aphids damage the plant by sucking out the cell sap. Although each aphid is a very minute creature, the number is generally so high that the collective drain on the plant system as a result of so many aphids feeding simultaneously is so huge that the plant generally succumbs quicker to this pest than to larger pests like the caterpillars mentioned above. However, as each individual insect is minute and delicate and spends the whole of its life on the foliage or tender twigs it is quite easy to keep this pest in check by spraying or dusting a good contact insecticide. As this pest has a tendency for very quick multiplication, the insecticidal treatment has to be repeated as soon as the aphid population is found to have built up again after a particular treatment.

Control Schedule

Taking into consideration the different important pests of pulse crops mentioned above, it should be clear that the farmers interes-

ted in these crops should keep themselves prepared for the following three-pronged attack against insect pests:

(*a*) *Soil Treatment against Cutworms and other Insects Hiding below or on the Soil Surface*

A thin top layer of the soil should be treated with a strong persistent soil insecticide, particularly in areas subject to cutworm attack year after year. This can be done just before or after sowing, or the insecticidal dust can be raked in even at a later stage, depending on the time when cutworm attack starts in the region. This treatment will not only poison the cutworms hiding in the soil during the day, but it will also take care of pests like the gram pod-borer, the Gujhia weevil, etc. which have a somewhat similar habit in this respect.

(*b*) *Mechanical Collection and Destruction of Several Pests in a Common Compaign*

As far as possible, common campaigns can be organized, as soon as the pest attack starts, for the collection and destruction of such pests as can be easily spotted out, e.g. the leaves infested by leaf-miners, or even pea stem-borers, the twisted deformed pods attacked by the red gram pod-borers and cutworms whose presence can be detected by the freshly cut shoots dragged into the soil. This campaign can be successfully carried out only when the pest attack has just started. It is an operation suggested for the attack to be nipped in the bud.

(*c*) *Insecticidal Treatment of the Crop*

If the trouble persists in spite of the first two operations or because they have not been carried out, then the crop should be treated with a penetrating formulation of a good persistent insecticide which acts both as a contact insecticide and as a stomach poison. This treatment should take care of practically any or all of the pests. For example, it can kill the gram pod-borer mainly by contact effect while it is eating the developing grain in the pod from outside, it should poison the cutworms when they feed on the trea-

ted shoots, it should provide a lethal dose to the adults laying eggs in the crops, it can also reach the leaf-miners within their galleries as the epidermal layers covering these galleries do not offer adequate protection against sprays and it can certainly control pests like aphids. The main snag in this approach which should be carefully guarded against is that, as already mentioned, at times the leafy portions of the leguminous crops are used both for human and for cattle consumption. Hence, extreme care is needed to avoid residue hazards.

CHAPTER VII

PESTS OF OILSEED CROPS

THE group of oilseed crops is quite a heterogeneous assemblage of economic plants. It appears to be a good example of convergent evolution in which plant species belonging to altogether unrelated families have got specialized in oil production. However, there is little or no sign of convergent evolution so far as any other character of these plants is concerned. The result is that the pest problem is different in the case of different oilseed crops. The pests of coconut are being dealt with in a separate chapter because, while all other oilseed crops are annuals, the coconut gardens are perennial. Hence, coconut can better be described along with other plantation crops as the overall strategy of pest control in perennials has to be different from that in the annuals.

PESTS OF MUSTARD CROP

There are three important pests of mustard crop in the country, namely, the mustard aphid, the mustard sawfly and the painted bug. Of these, the first two are being described here in detail.

THE MUSTARD APHID

(*Lipaphis erysimi* Kaltenbach)

(*Plate XVIII*)

The most serious pest of the mustard crop is the aphid. Besides brassicas to which mustard belongs, this pest attacks a number of other economic plants, particularly those of the family Cruciferae. Like many other important aphid pests, this species has a very wide distribution in the world.

Comparatively, the aphid group of insects is fairly compact both from the structural viewpoint and that of habits, biology and life-history. Hence, comparatively a fewer number of species

have been studied in all their minute details and our overall pooled knowledge on the group is presumed to be applicable to many of the individual species.

The aphids are small (about 2 mm), generally globular insects with piercing and sucking mouth-parts. A special structural characteristic of this group which is not shared by other insects is the possession of a pair of small tubular structures projecting out from the dorsal surface of the posterior region of their body; these have been referred to by various names like siphons, cornicles, etc. Rather unlike other groups of insects, many of the important Indian pests of this group are serious cosmopolitan pests. This rather extraordinarily cosmopolitan nature of distribution of individual species of aphids may be attributed to their dispersal being often wind-borne in rather higher strata of wind currents.

Although each individual insect is small in size, its sucking propensities are very high. It pierces its hypodermic syringe-like proboscis into the tender plant tissue and goes on sucking out the plant sap. Experiments with some species have shown that once the mouth-parts are securely inserted in the plant tissue, the body of the aphid can be sevred off from the head and even after that the sucking pump of the aphid continues to work and the sucked-out sap continues to drop down from the severed head. The normal aphid excrete a sweet watery solution called honeydew and thus gets rid of excess water sucked out from the plant. The honeydew thus secreted is very much liked by a number of other insects, particularly those of the ant family who for the sake of ensuring the supply of this sweet liquid protect the aphids and also provide them transport. The economic significance of all these activities cannot be properly gauged by visualizing the actions of a few individuals, but one can well imagine what the plant faces when hundreds and thousands of these minute creatures continue to inflict numerous punctures on each leaf or tender shoot. In mild cases, the shoot wilts and in severe cases it gets killed. The honeydew produced by such a large number of individuals covers practically the whole surface of leaves and the tender shoots and a kind of black mould develops on this which not only gives a black unhealthy look to the crop but also

interferes with the photosynthetic activities of the plant. There are a number of species of aphids the population of which does not rise to such proportions as to cause much direct damage. All the same, some of them are extremely harmful because they transmit virus diseases of crop plants. In such cases, even a very small population of the species can cause havoc to the crop because once they transmit the disease to the crop, there is practically no cure possible.

In temperate climates, the life-history of aphids is generally very complicated. Detailed studies on some species have shown that not only does there exist polymorphism in different generations but there is also considerable variation both in physiology and habit of different kinds of individuals of the same generation. In cold countries, the typical pattern of life-history on the whole is that in autumn a generation of sexuals, i.e. males and females, is produced. These pair and lay fertile eggs which are capable of overwintering on the food plant. These eggs hatch during the following spring into parthenogenetic individuals which are not only able to produce the progeny without mating but which instead of laying eggs are able to give birth to young ones directly. This not only quickens reproduction but also cuts down mortality. The young ones develop into mature adults within a few days and being all females begin to give birth to another generation. A number of such generations continue to be produced and as these are mostly wingless, their population goes on mounting on the same plant, the vitality of which goes on getting more and more sapped. However, at times a variable proportion of winged individuals is also produced and they help in the dispersal of the population. The proportion of the winged individuals goes on increasing as the physiological state of the crop becomes less suitable for the aphid till, at times, the whole horizon becomes practically covered with winged aphids. This leads to a very large-scale dispersal and the individuals which happen to alight on suitable hosts begin to breed parthenogenetically. This in colder countries continues till autumn when the sexual oviparous generation is once again produced.

In warmer countries like India, the sexual part of the life-cycle has not been commonly observed. Here the aphid population

generally makes its appearance in most species sometimes during winter and it continues to breed parthenogenetically till the end of spring when winged individuals are produced and large-scale dispersal takes place. During this time, under Indian conditions, sometimes the population of predatory coccinellid beetles may build up, which may exercise some control on the increase in population of aphids. The population, however, dwindles mostly due to climatic reasons and practically disappears for the whole of the summer and also most of the autumn. *This is what happens in the case of the mustard aphid.* The problem for this pest in India is not how to get over winter but how to pass the summer-time; a modification in the normal life-cycle is expected but the details have not been studied so far. There are, however, a few species like *Aphis gossypii* on cotton, *Rhopalosiphum maidis* on crops of the grass family, *Aphis cytisorum* on leguminous plants, etc. which are quite adaptable and breed practically throughout the year under Indian conditions although they are cosmopolitan in distribution and are serious crop pests even in temperate regions.

The control of such fast-multiplying pests like the aphids would have been extremely difficult but for the fact that most of them are quite susceptible to a number of contact and systemic insecticides. However, the applications of these insecticides have to be repeated at very short intervals unless a rather persistent insecticide is chosen, because otherwise a few individuals, which escape destruction or which alight on the crop later, soon build up a high population again. A number of systemic insecticides, so-called because they are absorbed by the plant system and are translocated to different parts of the plant, have also come into the market. Aphids are generally very susceptible to systemic insecticides which they suck along with the plant juice and which can stay for a fairly long time within the plant to keep it free from aphids. However, the main bottleneck in popularization of these systemics is the health-hazard involved in their use. Particularly in India, there is very little definite information as to how long these toxic chemicals remain in the food or fodder portions of the crop and the lower limit at which if present, it will not be toxic to human and cattle consumers of such produce.

THE MUSTARD SAWFLY

(*Athalia promixa* Klug.)

(*Plate XIX*)

Although its common name suggests that it may belong to the group of such a harmful insect as the housefly, it actually belongs to the group of such a useful insect as the honey-bee. All the same, it is an enemy of the farmer and a very harmful pest of mustard and other crops of the family cruciferae. It has certain peculiarities both in structure and habits which are of both academic and applied interest. It is in the larval stage that the pest damages the crop by voraciously feeding on the leaves of the young crop.

The pest is distributed practically throughout India. It is a pest of cold weather, its activity being confined generally to the period from October to March although in certain western regions it is reported to be prevalent round about August.

The adult is a rather thick-set insect with a mixture of yellow and brown markings on the body and a dark reddish-brown colour on the wings. It has two pairs of wings like a wasp rather than one pair like a fly. Unlike wasps it is not a good flier but like wasps its activities are diurnal and it is often observed in the field performing slow short flights from plant to plant. Its egg-laying organ is highly specialized for slitting open the margin of the leaves within which it lays eggs singly. The ovipositor is serrated and saw-like; this explains the common name of this pest and its allies. Each female is capable of laying a large number of eggs which in some cases may reach up to about 150.

The eggs hatch out depending on temperature within a period which may vary from less than a week to about a month. The young larva is greenish-grey in colour and its body surface is hairless. It begins to feed on the margin of the leaf; and as it grows, its colour goes on getting darker and darker. Its feeding activities are generally confined to mornings and evenings and during the day it prefers to descend to the soil surface. The most interesting and important characteristic of the larva,

however, is that unlike the larvae of most other groups of the order Hymenoptera to which it belongs, the sawfly larva resembles, in general contour of its body, the caterpillar of Lepidoptera and both inexperienced students and farmers are likely to be misled. Like Lepidopterous caterpillars the Hymenopterous larva has biting and chewing mouth-parts and the nature of damage by the two groups of larvae is very similar. Also, like most of the Lepidopterous cutworms these are also in the habit of curling up, falling down and feigning death at the slightest disturbance. On slightly closer observation, however, one can easily distinguish these two groups because the sawfly larvae have eight pairs of prolegs borne on the abdominal portion besides the three jointed legs borne on the thoracic region. On the other hand, the Lepidopterous caterpillars have at the most five pairs of prolegs on the abdomen besides three pairs of thoracic legs.

The larval period lasts from about a week to about a month and the full-grown larva is generally less than 2 cm in length. For pupation it generally goes into the soil wherein it prepares a cocoon made of silk buttressed by soil particles and the pupal period lasts from a little over a week to about two weeks. There are a number of generations (3 to 10 or so) during the year in the different regions of the country. The pest has its own enemy in the form of another hymenopterous parasite which attacks the larval stage.

The characteristic which can be exploited for the control of this pest is the larval feeding on the leaves which can be poisoned by persistent insecticides. The insecticides chosen should have a combined action of both a stomach poison and a contact poison, so that the adults while laying eggs and flying from plant to plant in the field should also pick up a lethal dose before they are able to lay their full quota of eggs; the more quick-acting the insecticide the better will be the effects but preferably it should also have enough persistence to go on poisoning young larvae for as long as possible. The third but conflicting requirement which has to be met is that the hazards to consumer's health must be avoided and treated foliage should not be used for cooking as vegetable or for salad. This important requirement necessitates that in the case of small-scale farming and kitchen gardens, chemical treatment should not be resorted to and mechanical picking of

the larvae or shaking them down in a pail of kerosenized water should be enough to keep the pest in check.

Control Schedule Against Pests of Mustard

Taking the important pests of mustard into consideration, the farmers with a large acreage under mustard crop should be ready to follow a control schedule somewhat on the following lines:

(1) If the young crop is infested with the painted bug or larvae of the mustard sawfly, it should be treated with a persistent insecticide like *gamma* BHC or endosulfan which act both as contact and as stomach poisons. The treatment may have to be repeated at an interval of about two to three weeks if the infestation continues.

(2) The above treatment will have to be repeated at a later stage when aphids start appearing on the young inflorescence.

The point which has to be kept in view, however, is that the leaves of the treated crop should not be used for consumption by man or cattle.

Pests of Groundnut

The important pests of groundnut are the red hairy caterpillar, the groundnut leaf-miner, the stem-borer, the aphids and the termites. Out of these, the first and the last have already been described and the second and the third are being discussed below. For the aphid pests, a reference may be made to the description of the aphid pests of mustard because they are very similar both in general life-history and in control measures.

GROUNDNUT LEAF-MINER

(*Stomopteryx subsecivella Zeller*)

This pest is fairly specific to groundnut, although it has been also reported on a number of other plants in different parts of India. The small caterpillars mine, skeletonize and web together the leaves of its food plant. It is particularly serious in south India where it is reported to be known in the local dialects as *surulpuchi* or *mudupuchi* and where in badly-infested fields the plants are so

severely damaged that they appear as if they have been victims of fire. Its scientific name has undergone several changes and it has been referred to in literature as *Anacampsis nerteria*, *Aproaerema nerteria* and *Stomopteryx nerteria*. Its world range of distribution includes India, South Africa, Sri Lanka and Indonesia.

The adult stage is a small moth rather bronzy in colour and with a wing-span of less than a centimetre. It belongs to the family Gelechiidae. Its activities are nocturnal and is strongly attracted to light: during the day, it remains hiding under clods, in crevices, etc. It lays eggs singly on its food plants and one female can lay up to several hundred eggs. The eggs are generally laid in depressions on the plant surface and their shape under the microscope has been described to like that of a groundnut pod i.e. the contour is irregularly elongate, the surface coarsely pitted and the colour pale green. Hatching takes place within a few days, generally in three days or so. The newly-hatched larva is about 1.5 mm. It wanders about for a little while and then mines the leaf which in a few days shows whitish-brown streaks representing the mines the interior of which is lined with a layer of silk. After about eight day's life as a miner, the larva bites its way out and webs together a number of leaflets, making a small silk-lined chamber for itself. The full-grown larva is 6 to 8 mm in length and dirty-green in colour. A special peculiarity of the larva which is to develop into a male moth is that its pair of violet testes is clearly visible through the larval spin. The larval period is 9 to 17 days. Pupation takes place in a closely-woven torpedo-shaped cocoon which is about 9 mm in length and which is rather loosely attached to the sides of the larval chamber. The pupa is about 4.5 mm in length and yellowish to reddish-brown in colour. The pupal period is about four days. Under suitable conditions of climate and availability of food, this insect can breed throughout the year.

The pest is subject to the attack of at least two pupal and three larval parasites in south India.

The peculiarities of its life-history will show that once the larva mines into the leaf, it will be in comparative safety against chemicals, particularly in dust form. Hence, at this stage, certain rather penetrating sprays of contact insecticides may be tried. Later,

when the larvae come out of the mines and prepare their own chamber by webbing the leaves, the dust formulations may be more effective. The most rational approach, however, is to treat the crop with a persistent chemical spray before the larvae have gone into the mine. This can be timed by means of light-traps which are quite effective in attracting the adults. Hence, the crop should be treated by a persistent chemical as soon as the moths begin to be attracted to the light-traps which should be specially set up for the purpose, so that when the hatching of eggs takes place, the just-hatched larvae may pick up a lethal dose of the insecticide before they enter the leaf tissue. This operation should be followed up by a careful observation on the appearance of a few mines and larval chambers which might come up in spite of the insecticidal treatment; these should be got collected and destroyed so that the population of the pest is not allowed to build up.

GROUNDNUT STEM-BORER

(*Sphenoptera perotetti*, Guerin)

This insect does not seem to have been reported as a pest from outside India. In the adult stage, it is popularly known as jewel beetle (family—Buprestidae) with a striking metallic shine over a dark-brown colour. Of course, it is rather small in size (about 10 to 12 mm in length) as compared to other more brilliant species of jewel beetles. Its larvae bore into the stem of the groundnut plant and often travel downwards, tunnel the main root, and kill the plant. Besides groundnut, it attacks a number of other leguminous plants like cowpea, red gram, horse gram, wild sunnhemp, etc.

The mother-beetle deposits its eggs generally on the basal region of the main stem or even on the ground. The eggs are flattened like scales and are eliptical in outline. The larva is a typical flat-headed Buprestid grub with a broad anterior and a tapering posterior region. It cuts its way into the stem and feeds there. When full-grown, it is generally a little less than 4 cm in length and white in colour. It pupates in the larval burrow and the pupal colour is milky-white. The pupal period lasts about 10 days after which the adult emerges to start the next generation.

In the past, its control was considered to be very difficult and the only precaution that could be suggested was to uproot the affected plants and destory the same along with the larval and pupal stages infesting the same, so that the adult may not be able to emerge and lay eggs on other healthy plants. Now, however, there are better insecticidal chemicals which can be tried but the studies carried out on the habits and biology of this pest are so meagre that it is not possible to suggest a rational approach for the control of this on a large scale. Further studies are very much needed on this pest.

Control Schedule Against Pests of Groundnut

Taking into consideration the various important pests of this crop, the following guidelines may be suggested regarding the control schedule:

(*a*) In areas where termites cause appreciable damage after sowing, the soil should be treated with a good persistent soil insecticide like aldrin. The insecticide should be applied at the time of sowing in such a way as to concentrate the pesticide in the immediate vicinity of the seed and seedlings. For example, this can be ensured by applying the insecticide in the furrows along with the seed.

(*b*) With the first shower, light-traps should be set up partly as a control measure, but mainly as an indicator of the emergence of moths of the red-hairy caterpillar. As soon as the moths begin to come to the light-traps, a regular campaign should be started for the collection of (*i*) egg-masses of hairy caterpillars, (*ii*) leaves showing signs of leaf-miner attack, (*iii*) leaves having initial colonies of aphids, and (*iv*) shoots infested with stem-borers. Even small boys and girls can be trained for this job. If the campaign is effectively organized on a co-operative basis in a large area, the main pest problems of groundnut cultivation can be nipped in the bud and more costly and less certain chemical control operations may not be found necessary.

(*c*) If due to some reason or other, the above campaign has not been quite effective and aphids and caterpillar pests are found to be serious, then the crop should be treated with a persistent insecticide like *gamma* BHC which is quite effective against aphids and young stages of hairy caterpillars and is also likely to

keep other pests under check. Thereafter, the crop should be kept under observation for two to three weeks and if the trouble due to the hairy caterpillar still persists and or if the leaf-miner and the stem-borer are also raising their heads, then the crop should again be sprayed with a persistent insecticide. The insecticide chosen should be quite toxic to the hairy caterpillar and aphids and it also should leave an effective toxic residue which can keep on poisoning the larvae of the leaf-miner and the stem-borer and also the adults of these pests when they move about among the treated foliage. The success of these operations will depend on the large size of the acreage on which simultaneous control operations are carried out on a co-operative basis.

Pests of Sesamum

There are three important pests of the sesamum crop in the country. These are all the leaf and pod caterpillar, the sphinx moth and the gall-fly. The first two of these three are being described below:

TIL LEAF AND POD CATERPILLAR

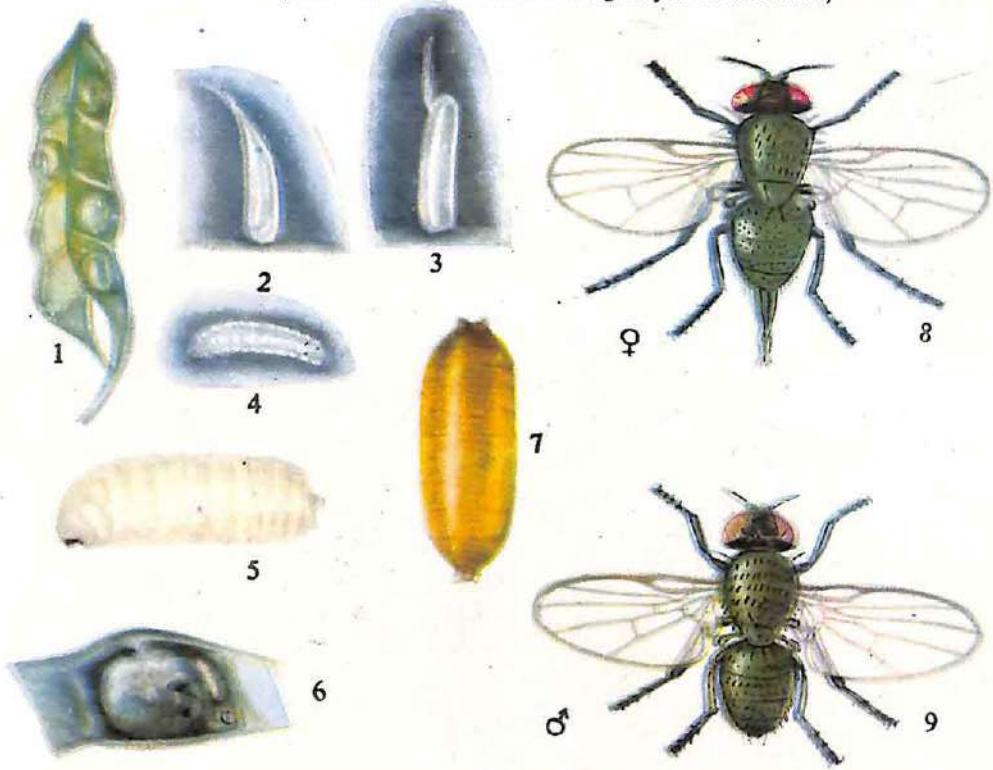
(*Antigastra catalaunalis* Duponchal)

(*Plate XX*)

This is a serious pest of *Til* (*Sesamum orientale or indicum* Linnaeus). However, it has also been found on a few other wild species of the genus *Sesamum* which seem to sustain this pest when cultivated *Til* crop is not in the field. The larval stage damages both the apical shoot and the young pods. An early attack kills the plant as a whole but the infestation of shoots at a later stage hampers the further growth and flowering processes. Besides India, the species (*Antigastra catalaunalis*) has been reported from Europe, Africa, Cyprus, Malta, Indonesia and South-East Asia.

The adult stage is a medium-sized moth with a wing-span of 15 to 20 cm. The fore-wings are reddish-yellow in colour and there are zigzag indistinct reddish decorative markings on them; the hind-wings are pale-yellow and rather transparent. Their activity is nocturnal and they hide during the day under fallen leaves, etc. But during night they are positively phototropic and are attracted to

(Plate XVII—Tur Pod-Fly *Agromyza obtusa* Mall.)



1. Pod of *Cajanus cajna* opened to show oviposition 2. Egg, freshly laid 3. Egg, fully developed 4. Larva, freshly hatched 5. Larva, full-grown 6. Damaged seed in pod 7. Pupa 8. Adult fly, female 9. Adult fly, male.
(*Ind. J. Agri Sci.*, Vol. VIII, Plate V)

Plate XVIII—MUSTARD APHID

Mustard twig covered with innumerable aphids on inflorescence and pods. Picture on left hand (*bottom*) represents winged adult, while other enlarged pictures show wingless individuals.
Entomology Division Collection, I.A.R.I.)

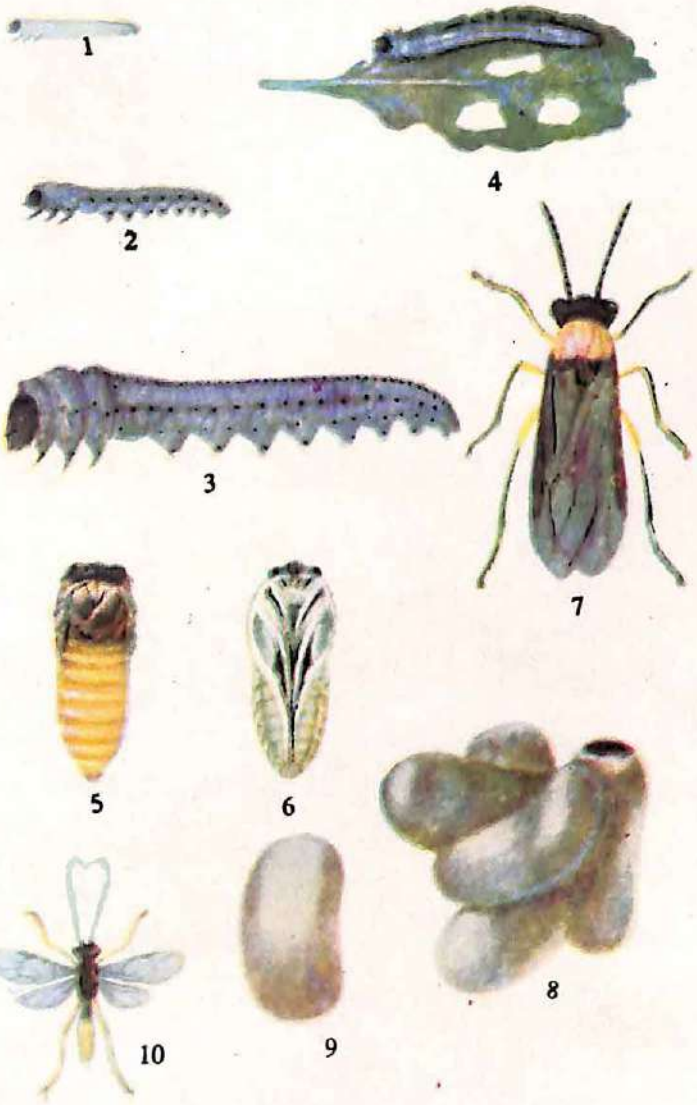


Plate XIX—MUSTARD SAWFLY

1. Young larva 2. Half-grown larva 3. Full-grown larva 4. Larva feeding on mustard leaf 5. Pupa, dorsal view 6. Pupa, ventral view 7. Imago 8. Cluster of cocoons 9. Single cocoon 10. Parasite.

(*Indian Insect Life*, Plate IX, p. 164)

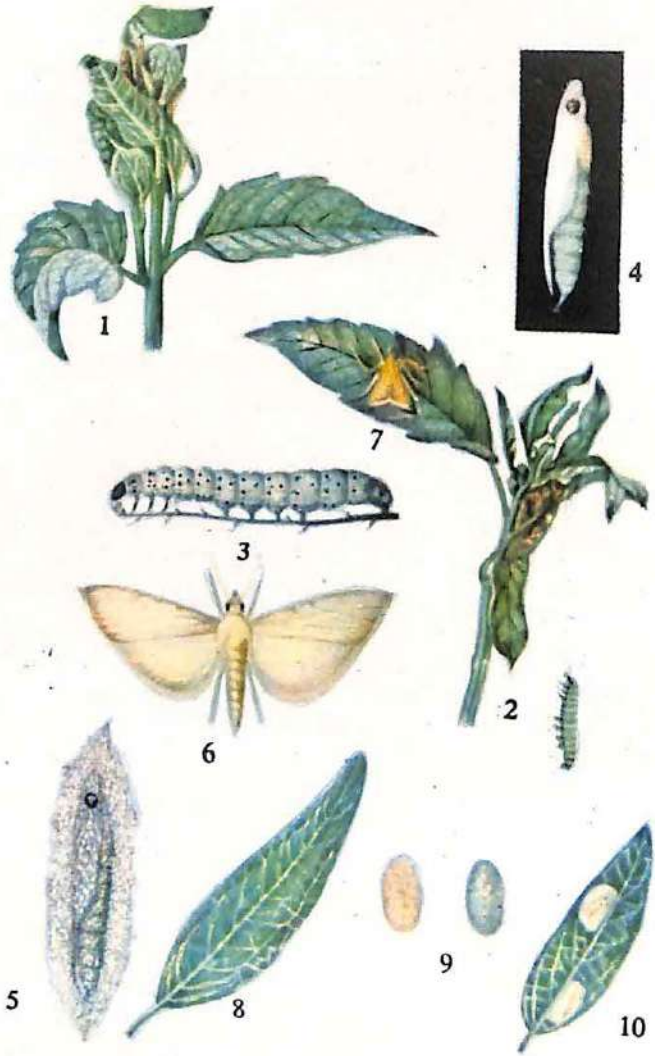


Plate XX—Til Leaf and Caterpillar

1. Shoot of Til (*Seasamum indicum*) rolled by larva 2. Another shoot, showing larva as it lets itself down by silken thread 3. Larva 4. Pupa 5. Pupa in its coocon 6. Moth 7. Moth on leaf 8. Eggs on leaf 9. Eggs 10. Newly-hatched larvae feeding on epidemis prior to webbing the shoot.

(*Some South Indian Insects*, Plate XXVII, p. 441)

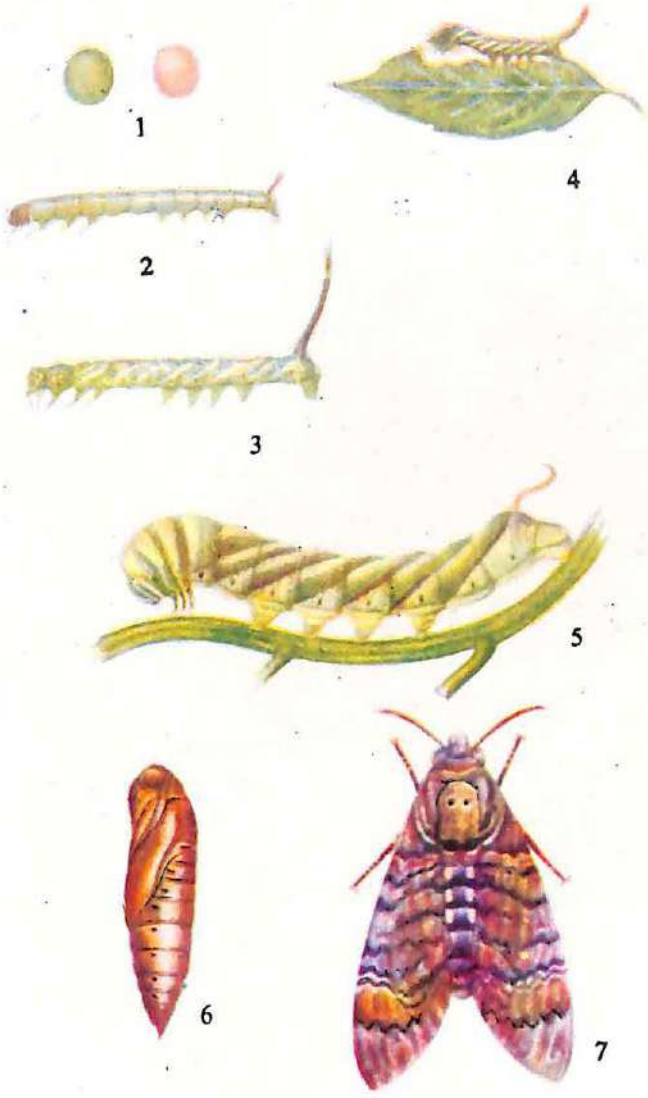


Plate XXI—HAWK MOTH

1. Eggs 2. Young larva 3. & 4. Half-grown larvae
5. Full-grown larva 6. Pupa 7. Moth

(*Indian Insect Life*, p. 464)

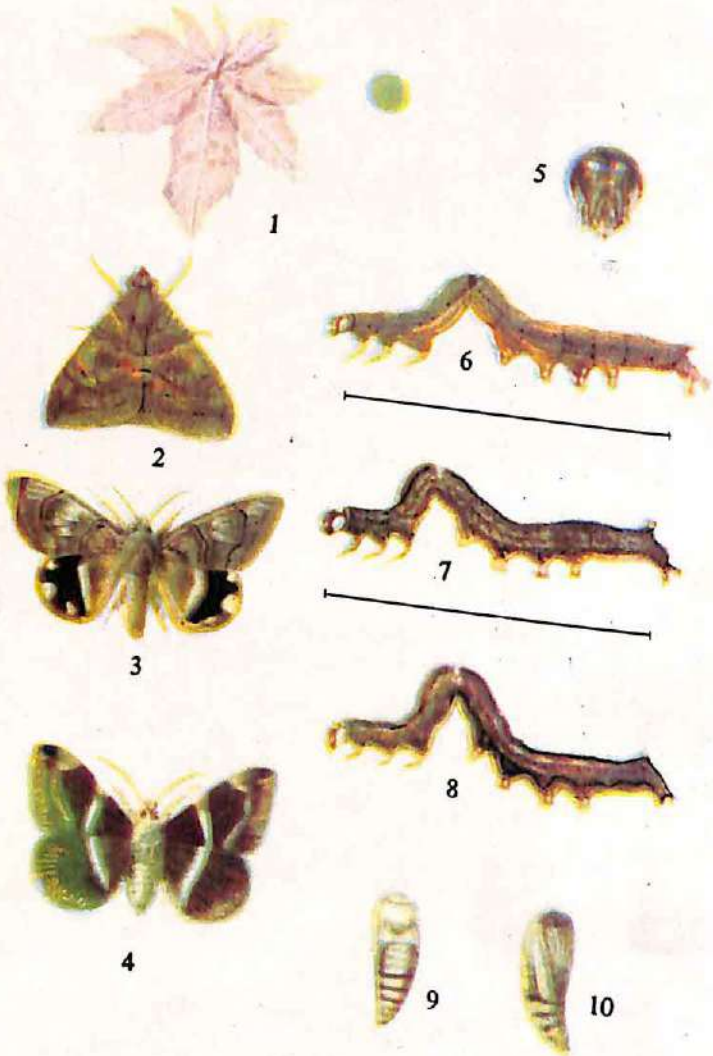


Plate XXII—Castor Semi-Looper

1. Eggs on leaf 2—4. Adults 5. Larval head 6—8. Larval stages 9 & 10. Pupal stages.

(*Mem. Deptt. Agri. India*, II, pp. 59 & 64)

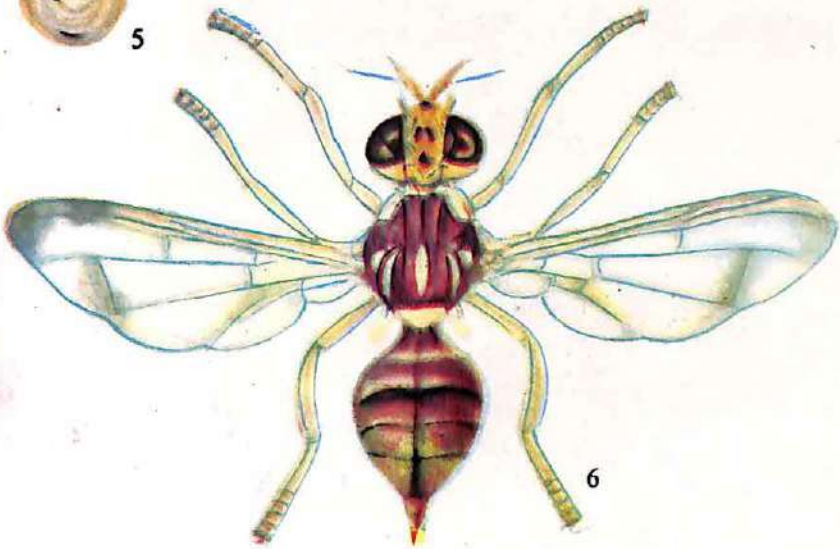


Plate XXIII—FRUIT FLY

1. Maggots in fruit 2. Larva 3—5. Pupa along with details of extremities 6. Adult.

(*Some South Indian Insects*, Plate XVI)

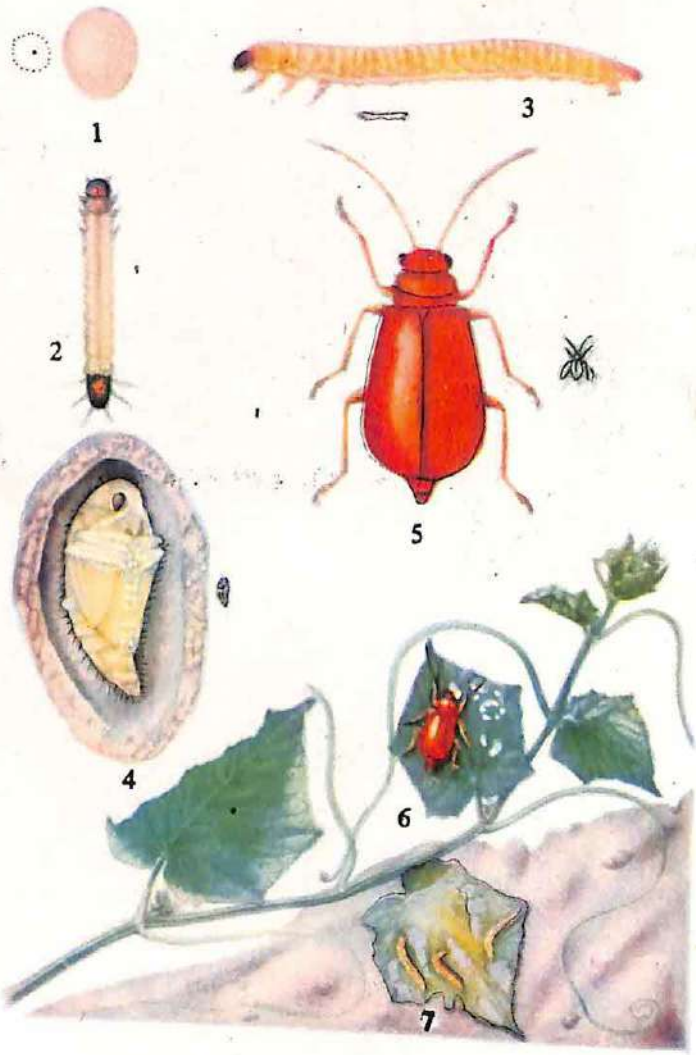


Plate XXIV—Red Pumpkin Beetle

1. Egg 2 & 3. Young and full-grown grubs 4. Full-grown grubs, feeding on fallen decaying leaf 5. Pupa in pupal cell 6. Adult beetle 7. Beetle feeding on cucumber leaf.

(*Proc. 2nd Ent. Meeting*, p. 302)

light. They lay eggs singly generally on the underside of leaves and on the apical portions of the growing shoot. The eggs are greenish in colour and they hatch out within two to seven days, depending on the season. The just-hatched larva is about 2 mm in length and somewhat whitish in colour; later on, the colour slowly changes to green and the full-grown larva, which is about 15 mm in length, is also speckled with dark-brown markings. The characteristic habit is that soon after hatching and feeding for a little while on leaf epidermis or even mining the leaf, they bind together the tender leaves of the growing shoot with the help of silken threads produced by them; they prefer to remain within the bunch foliage thus rolled and spun together in a sort of webbed mass. The size of this rolled bunch becomes bigger and bigger as the larva grows in size and incorporates more and more of the nighbouring foliage. Thus, the larvae prepare their own abode of safety and plenty. Despite this precaution, the larvae are often attacked by a Hymenopterous parasite. When the pods are formed, the larvae bore the pods and feed on the seed.

The larval period lasts from about 10 days to more than a month. For pupation, the full-grown larva descends to the ground and goes either under the fallen leaves or into cracks and crevices. The pupa is greenish when just formed but it becomes brown later on. The pupal period varies from about 4 days to about 20 days. Thereafter, the moth emerges which begins to lay eggs for the next generation within four to five days after emergence. In the laboratory, the pest completes upto 14 generations in a year and in nature this number depends on the seasonal variations in temperature and humidity.

It will be seen from the foregoing account that because of the larval habit to live and feed inside the rolled-up foliage, the success of mild dusting or spraying will be limited in the control of this pest. The rational approach against this pest, therefore, will be first to give a protective covering of a persistent insecticide which should quickly poison the moth before it is able to lay its full quota of eggs and later on to collect and burn the rolled-up bunches of foliage as soon as they appear. The timing of the first operation should depend on the experience of earlier years as to when the attack on the crop is likely to start.

HAWK MOTH

(*Acherontia styx* Westwood)

(*Plate XXI*)

This insect is more striking in drawing our attention than in being injurious under Indian conditions although it is capable of inflicting very heavy damage as it actually does sometimes in this country and as its near-allies often do in other countries. It belongs to a group of insects of the family Sphingidae which are commonly referred to as Hawk Moths, Sphinx Moths or Death's Head Moths. All these common names are based on structural or behavioural characteristics of the usually robust insect the adult of which is a large thick-set moth with wings having a span upto several centimetres. These insects are swift fliers and they often make hawk-like darts to a light source soon after dusk. The full-grown caterpillars which attain a length up to 5 cm or more and also a thickness of more than 1 cm are in the habit of retracting and drawing in the head and some of the anterior segments of the body into a sort of sphinx-like posture; this along with a horn-like projection from the posterior end of the abdomen enhances the ferocious appearance of these larvae which otherwise have quite a plump body with a pleasant mixture of soft colours.

The species (*Acherontia styx*) which is common in India and which has been described as a pest of *Til* is also reported from Indonesia, Sri Lanka, the Philippines and Burma. Besides sesamum it has been, found to damage potato, brinjal, lablab, etc. In urban areas like Delhi, at times it attacks ornamental plants like balsam. The moth is also harmful to apiarists because it tries to suck out honey from the honey-comb although at times it is stung to death for this attempted robbery.

The adult of *Acherontia styx* is a large reddish-brown moth with a wing-span of at times more than 10 cm. The forewings possess a mixture of dark-brown and grey ornamentation with dark-blackish wavy markings and a prominent yellow spot on each wing. The hind-wings have an ochre background on which there are two broad dark-brown wavy cross stripes. The head and thorax are also dark-brown and on the latter there is a prominent Death's Head mark.

The abdomen is ochracious in general hue with dark-brown cross stripes.

The moths lay eggs singly generally on the under-surface of the leaves of the food plant and the eggs are fairly large; their colour is at first greenish-white but later on it turns to yellow. Hatching takes place within a few days and the just-hatched larva is pale-yellowish in colour. Soon it begins to feed on the leaves and develops broad green stripes running obliquely along the dorso-lateral surface. In general contour, it is a typical sphingid caterpillar with the characteristic head and caudal horn. On the whole, it looks quite ferocious and venomous, although it is quite harmless and safe to handle. When the larva is full-grown, its colour undergoes a rather drastic change to brown and at this stage it descends from the plant to the ground and finds a suitable place for entry into the soil wherein it pupates. The larval period is unusually long and at times it lasts upto two months or more; the pupal stage is also almost equally long.

The changes in the larval colouration, the general contour and colourful ornamentation of both the larva and adult suggest the general phenomenon of protective mimicry. The feeding stages of the larvae are fairly in conformity with their foliar surroundings and later when the time for descending to the ground comes the colour-change again serves the same purpose. The impression of ferociousness created both by the larvae and adult is obviously meant to dodge their predators. It is no wonder that such large-sized insects should have some mechanism against predators because their very size makes it worthwhile even for large predators to search for and prey upon them. There are also one Dipterous and one Hymenopterous parasites which attack the larval stage.

From the characteristics described in the foregoing paragraphs, it is clear that a good stomach poison, preferably with contact effect as well, should be the proper weapon of control for large-scale operations against this pest. On a small scale, however, as in flower-beds, hand-picking should be quite enough for such large-sized insects which are harmless to handle.

Control Schedule for Pests of Sesamum

Considerations for formulating the schedule

(*a*) Of the three important pests of sesamum, no chemical control is known for the gall-fly. The only method recommended against this pest is the mechanical collection and destruction of the infested material. The larvae of sphinx moths are quite large in size and can be mechanically collected and destroyed. The caterpillars of the leaf-roller make shelters for themselves inside the webbed leaves and thus mechanical collection of the affected leaves and shoots has been recommended. As all the three important pests can be checked by mechanical means, campaigns for mechanical control of the pests is quite feasible.

(*b*) The *Til* leaf-roller and sphinx caterpillar start appearing in the early stages of the crop and continue for a long time. Hence, only long-persisting insecticides, having both contact and stomach poison effects, can be recommended.

Control Schedule

In view of the considerations mentioned above, the following control schedule is feasible :

(1) Two campaigns for mechanical control should be carried out every season. The first one in the early season of the crop should be for the collection and destruction of (*i*) the sphinx caterpillar, and (*ii*) leaves and fruits affected by the leaf-roller. The second campaign should be for the collection and destruction of plants attacked by the gall-fly and it should be carried out as soon as the damage by the gall-fly starts.

(2) If the leaf-roller and sphinx caterpillar are serious despite the above mentioned campaigns, then the crop should be treated with a good persistent insecticide form. This treatment may be repeated at an interval of 25 days, if necessary. More than two sprays are not likely to be required per season.

Pests of Castor Crop

There are three important pests of this crop, namely, the semi-looper, the capsule-borer and the gall-fly. The first of these three is being described below in detail :

CASTOR SEMI-LOOPER

(*Achaea janata* Linnaeus)

(*Plate XXII*)

This is one of the worst pests of the castor crop. Its caterpillars cause severe injury to the leaves of the castor plants which are at times stripped bare. Further, a rather rare peculiarity of this insect is that unlike adults of most lepidopterous pests, its moth is also injurious and is one of the common fruit sucking moths. It is well-known that most of the lepidopterous pests are harmless in their adult stage and it is only in the larval stage that they damage the various crops or commodities. The situation is different in the case of several species of fruit-sucking moths which are serious pests of citrus fruits. In these cases, it is the adult moth stage that inflicts damage on the citrus fruits, while in most cases the larval stages feed on various species of wild plants. The peculiarity of *Achaea janata* is that in its larval stage it is a serious pest of castor and in its adult stage it is a serious pest of citrus. Judging from this angle, this species may be considered to occupy a very special position in economic entomology.

Besides the name mentioned above, this pest has been referred to in literature under a variety of names, viz., *Ophiusa melicerta*, *Noctua tigrina*, *Achaea catella*, *Catocala traversa*, etc. Its world distribution includes India, Sri Lanka and Thailand.

The adult stage is a pale reddish-brown moth with a wing-span of 60 to 70 mm. Both the fore-wings and hind-wings have broad zigzag decorative markings and large pale and dark brown patches. They are crepuscular in habit, resting by day in hiding among fallen leaves, etc. and comming out at dusk. They lay eggs in a scattered manner on tender leaves. However, sometimes there is quite a prolonged pre-oviposition period extending upto three weeks or so. Each moth can lay several hundred eggs (up to 450 or more). The egg is comparatively large (about a millimetre in size) and has ridges and furrows on the surface radiating from a circular depression at the apex. Despite this large size, however, it is often difficult to spot out the egg on the leaf due to its blue-green colour. Hatching of the eggs takes place within two to five

days after oviposition and the larva emerges by biting a hole into the egg shell. The rest of the empty egg shell also forms the first meal of the just-hatched larva before it begins to feed on the leaf tissue. The first stage larva is about 3.5 mm in length and its first two pairs of sucker-feet are undeveloped. Hence, the gait of the larva is rather peculiar, the locomotory process involves the formation of a semi-loop of the larval body during each pace of progress. This explains the common name semi-looper as distinct from those which form full loops and are called loopers. Also, this peculiar bending posture of the body during locomotion along with a characteristic white mark on its head recalls the caste mark of some orthodox Hindus in south India and has led to its name *Dasari purugu* meaning a devotee worm in the Deccan area. Both the size and the voraciousness of the larva increase with age till after four or five moults the full-grown larva, 60 to 65 mm in length, is ready to pupate.

The variability of the larval colour pattern is very spectacular in this insect and some workers recognize four identifiable varieties of caterpillars in the third and fourth instars. However, the feeding propensities of all of them are very high. They feed from the edge of the leaf inwards up to the midrib and very soon they leave nothing of the plant but bare stalks. Singly they behave like ordinary caterpillars but when in large numbers they show a gregarious tendency and move in swarms. They are highly conspicuous against the background of the plant and exhibit prominently their brightly-coloured bodies and noticeable anal tubercles.

Pupation takes place both in the soil and under fallen leaves and other rubbish at the edge of the field. The larva seeks a somewhat hidden niche and prepares a loose cocoon of coarse silk to which particles of soil readily adhere. In some cases pupation may also take place on the plant within folded leaves. The chrysalis is about one inch long. The pupal stage lasts from ten to fifteen days after which the moth emerges. There may be five or six generations in a year.

The egg-stage is parasitized by *Trichogramma* sp. and the larval stages by other of three species of parasites.

The control of this pest has been considered to be very difficult. It becomes all the more complicated because the castor crop is

grown both for its seed which is a good source of castor oil and for feeding to the silkworm which is another Lepidopterous larva. Hence the castor crop meant to be fed to the silkworm cannot be treated with any good persistent insecticide. There are some recently developed possibilities for the use of microbial control of the pest but in that also there is a serious limitation due to the possibility of the microbial infection spreading to silkworms. In view of such limitations, the only rational approach is to keep the castor crop meant for seed suitably isolated from that meant for the silkworm and to treat the seed crop with good persistent insecticides. For those interested in a few isolated castor plants, the best course will be to get the semi-loopers picked up and destroyed. The same is the only possible control measure for those interested in the castor crop meant for the silkworm. Of course, under the supervision of trained entomologists, it should also be possible to kill the semi-loopers with the help of less persistent insecticides and to feed the treated crop to the silkworm only after the insecticidal residue on the foliage has practically disintegrated. The moths are attracted both to light and to bait traps containing slices of citrus fruits already damaged by the same pest as the fruit-sucking moth. These traps can be used at least for indicating a little in advance the impending infestation by the pest if not for a large-scale control of the same. Judicious spacing of citrus plantations and castor crops is an aspect for future consideration.

Control Schedule for Pests of Castor

The control schedule against the pests of castor should consist of the following two operations:

(1) A regular compaign should be organized to collect and destroy the semi-looper and the plant parts infested by the capsule-borer and the gall-fly.

(2) If the trouble persists on a large scale the crop should be treated with the dust or spray formulation of residual insecticide like *gamma* BHC, carbaryl or endosulfan. This treatment may have to be repeated three to four times at an interval of 15 to 20 days, depending on the build-up of the pest population. Of course, this recommendation is not ordinarily applicable in the case of castor crop meant for the rearing of the silkworm.

CHAPTER VIII

PESTS OF VEGETABLES

THERE are many types of vegetables and most of them with different types of pests. The present chapter, however, deals with the most important ones, *viz.*, the fruit-flies, the red pumpkin beetle, the brinjal-borer and the *hadda* beetles. The mustard aphid and the mustard sawfly which infest vegetable crops like cabbage, turnip, radish, etc. have already been described as pests of cruciferous oil-seed crops. Jassids, which are often serious pests of potato, lady's finger, etc. will be discussed along with the jassid pests of cotton.

FRUIT-FLIES

(*Plate XXIII*)

This is a group of very harmful insects which are serious enemies of orchardists and horticulturists. Most of them attack fruits either in their full-grown ripening stage as in the case of the mango, guava, loquot, etc. or in the early immature soft stage, as in the case of many cucurbits. The result in either case is almost complete loss of the attacked fruit. Those attacked early do not develop and those attacked late drop down and rot; even most of those which do not drop and are picked up normally are found to be unfit for consumption as they contain in the pulp a number of abominable white maggots which are actually the larvae of fruit-flies. The percentage of fruits which suffers such devastating infestations at times reaches practically a hundred and often a person who develops a new interest in kitchen-gardening feels completely frustrated when he is not able to pick up even a few healthy cucurbit fruits even of the bitter gourd. Large scale commercial growers do not generally suffer such heavy losses because they either will not grow such items as are likely to get so badly infested or else they will take enough precautions of various sorts. All the same, fruit-fly damage is often of such magnitude that orchardists and horticulturists have to reckon with them very seriously and have to modify their policy and plan keeping the fruit-fly infestation in view.

Although most of the species of fruit-flies are polyphagous—their list of food plants in some cases running into several hundreds there also exists quite an appreciable degree of specificity. Thus, for example, among cucurbit fruits, *Dacus dorsalis* Hendel has been reared only from bitter gourd and that too in captivity. On the other hand, *Dacus cucurbitae* (Coquillett) attacks a large variety of cucurbits and other vegetables and only occasionally fruits like those attacked by *D. dorsalis*. The preferences of the third important species of the fruit-fly, *Dacus ciliatus* Loew, are more like those of *D. cucurbitae*, while those of *Dacus zonatus* are rather intermediate between those of *dorsalis* and *cucurbitae*. The *Ber* fruit-fly (*Carpomyia vesuviana* Costa) is very much restricted in its host preference habit as it has been reported to infest the fruits of only a few species of the plant genus *Ziziphus* to which the *Ber* fruit belongs.

The adult stages of fruit-flies have generally quite a long life which in some cases can be more than a year. Their general make-up and size are very near those of the houseflies but they have ferruginous hues and hyaline wings. They lay eggs generally just underneath the skin of the fruit and from the punctures thus made oozes out a little fluid which often dries up in the form of a small globule or dot of resinous material on the fruit. The young maggots hatching from these eggs within a few days bore into the pulpy portion, where they spend the whole of their larval period of a few weeks. By this time, the attacked fruit generally rots and the larvae leave the rotten fruit and enter the soil for pupation. They pupate only a few centimetres below the surface. The pupal period generally lasts only for a few weeks but some species overwinter in this stage and in the case of the *Ber* fruit-fly, the pupal period has been reported to extend from 14 days to over 300 days. Practically all the species complete several generations during the year depending on the prevailing temperature and humidity.

The distribution of many species of fruit-flies is quite wide; this is not unexpected because fruits are carried from country to country in too many ways for quarantine operations to be really effective. However, it is rather surprising that one of the most destructive species of fruit-flies, viz., the Mediterranean fruit-fly, is not found in India. Some interesting ecological phenomenon is likely to be responsible for the absence of the Mediterranean fruit-fly

from the Indian sub-continent. A very important observation reported in recent years is that the Mediterranean fruit-fly population has got considerably reduced in Hawaii following the introduction of *Dacus dorsalis* there. The latter is reported to have displaced the former by laying eggs at the same point at which the former has already laid them. If this is so, then it is not unlikely that *Dacus dorsalis* has not allowed the Mediterranean fruit-fly to get established in India.

The habits of the adult are quite important for the control of this group of pests. The flies feed on honeydew, plant exudations and many types of sweet pulp and juices of ripe injured fruits, including the fluid oozing out from the punctures made for oviposition. The result is that they are quite responsive to several attractants which can be used for poison-baiting. As the adults are generally long-lived, they have to face the vicissitudes of weather and during periods of inclemency they generally huddle together in suitable ecological niches on the underside of leaves in nearby groves of trees and bushes and even under their dried leaves. This habit renders the flies susceptible to even mechanical destruction as very large numbers of flies can be collected from these niches which have to be determined by a careful survey of the locality. Of course, they can also be treated by insecticides in these niches.

More than two dozen species of insect parasites have been reported to be attacking the immature stages of fruit-flies. The majority of them parasitize the pupal stages of the fruit-flies. Obviously this pararsitic fauna exercises a good check on the population build-up of the fruit-flies; all the same, the control is not enough to keep the pest population below the economic level.

Keeping in view the peculiarities of the fruit-fly's life-history in general, the following steps can be recommended for its control. However, it cannot be over-emphasized that for the success of any of these control measures, it is necessary that it is carried out simultaneously in quite large and compact blocks. Work in small areas is almost certain to be a waste of effort.

(*a*) *Collection and Destruction of Infested Fruits along with the Larval Stages of the Fruit-fly.*

Despite all the modern techniques, this is the most practical

method of dealing with the fruit-fly problem, particularly under Indian conditions. It is unfortunate that it is not resorted to with any degree of seriousness. Detection of infested fruits, particularly in the late stages of infestation when maggots are still inside them is quite easy in many of the fruits. Most of them fall down, others get deformed and remain stunted. Hence, a regular campaign for the collection and destruction of such infested material should always be one of the most important items of a regular schedule for fruit-fly control.

(*b*) *Destruction of Pupal Stage in the Soil*

This is another operation which should be regularly resorted to. This can be achieved by treating the soil in the infested field and under infested trees with persistent insecticides. Even mere ploughing up the soil reduces the pest population by exposing the pupae to enemies and inclemencies of weather. The best time for this operation is early spring, a little before infestation is likely to start as has been determined by experience of earlier years in different localities. With a little study and experience of the local species, this operation can be precisely timed. It can also be resorted to during the active season when pupation takes place from generation to generation.

(*c*) *Destruction of the Adult Stage*

This can be achieved by (*i*) insecticidal applications, particularly in the ecological niches in which adults are observed to huddle together, (*ii*) by attracting them to traps and poison baits with the help of various attractants including sex-attractants, and (*iii*) by sterilizing instead of killing the attracted adults so that they may prevent the successful multiplication and breeding of those not lured by the attractants. The sterilization can be done by exposing the attracted adults to sterilizing radiations or by mixing chemo-steriliants instead of insecticides in the poison-baits. The attractant-baits can be exposed at various suitable places, sprayed or even applied with a brush at various suitable parts of the field or trees or even scattered at random in the field soaked in some suitable material.

Thus, it will be seen that there are very practical possibilities of destroying the fruit-fly pest in its various stages. Still fruit-fly control is rarely undertaken mainly because a concerted and co-operative action is called for and any effort by a lone individual is likely to prove a waste unless he is the owner of very large farms or orchards. In other words, the control of fruit-flies is entomologically easy but organizationally difficult. Not only is this pest very well suited for organising large-scale control campaigns but such campaigns are inevitable for successfully solving the fruit-fly pest problem.

RED PUMPKIN BEETLE

(*Rhaphidopalpa* Spp.)

(*Plate XXIV*)

There are several species of this pest reported from different countries right from East Africa through different parts of India up to Australia. Also, this pest has been described under several generic names but the two more commonly used are *Aulacophora* and *Rhaphidopalpa*. The corresponding pest in the New World has been generally described by the generic name *Diabrotica*.

As the common name indicates, this pest in the adult stage is generally a dark orange-coloured oblong beetle of about 5 to 8 mm in length. All the vegetable-growers even at the kitchen-garden level are fully familiar with these beetles. They have a special preference for the leaves of cucurbit plants except those of the bitter gourd (*Karela*) on which they have not been reported to feed to any appreciable extent. The commencement of their activity after winter generally corresponds with the early growing season of the spring crop of cucurbit vegetables and the damage done to the young seedlings is often so severe that the crop has to be at times sown several times, causing great loss of labour and seed and also great delay in the production of these vegetables which means much further loss because the early harvests fetch better prices in the market. The damage continues to be caused even in the later stages of the crop but it is not so spectacular as in the case of seedlings. The larval stage of this pest also does considerable damage as it bores

into the roots, stems and even the fruits on which the attack starts at the portion resting on the ground.

During winter, the beetles stay in a state of quiscence hiding in various suitable niches from the severity of cold. The places where winter is passed include any nook or corner where reasonable refuge can be ensured but dried-up cucurbit creepers and other crop refuse piled up nearby are quite convenient. Also, the beetles take shelter among grasses, weeds, bushes, etc. As soon as it begins to warm up, this overwintering population becomes active and comes out from its hiding places. At this time, the spring crop of cucurbit vegetables is in the process of germination and the overwintering population of the red pumpkin beetle finds the young cucurbit seedlings quite attractive and palatable. The result is voracious feeding which the young seedlings are generally not able to withstand. Also, the breeding activity starts at this very stage. Oviposition takes place near the base of the seedlings on which the beetles feed, provided the surface of the soil is suitably moist. The exact requirements for egg-laying do not seem to be fully understood because while some workers have recorded abundant egg-laying and larval population, others under somewhat similar conditions have failed to observe active oviposition and breeding. However, this much is quite certain that egg-laying does not take place if the soil surface has become dry and the hatching gets very adversely affected even if the soil surface gets dry after oviposition has taken place. Also, excess of moisture adversely affects hatching. There is a suggestion to exploit this fact in keeping the crop somewhat safe from this pest. The eggs may be laid singly or in batches and a single female is reported to be able to lay up to 300 eggs.

The incubation period of the eggs varies from 6 to 15 days, depending on environmental temperature and humidity and the larvae soon after hatching are quite active and begin to feed on the roots and stems which they readily bore into. They also cut holes in the leaves lying on the ground and feed under such concealment. They may even bore into the fruits from the side which touches the soil surface. However, at the end of every instar, the larvae enter the soil to moult and come out thereafter to feed again. There are four to five larval instars completed in about two to three weeks. At the end of the last instar when the larva is full grown,

it actually tunnels into the soil to depths varying from 1 to 25 cm and there it prepares an oval chamber for pupation. This pupal chamber made by the movement of the larval body round its longitudinal axis is quite impervious to water and it is believed that some secretion makes the walls waterproof. The pupal period varies from about one to three weeks. Thus, one full life-cycle may take from about four weeks to more than eight weeks. This period becomes much more prolonged in the case of the last brood of the year which hibernates in the adult stage for several months. There are generally three to four generations a year. There is no specific effective biotic check on this pest. Hence, it is not surprising that this pest is quite serious; what, however, is surprising is why it is not much more serious than what it is.

A comparative study of the seasonal history of the pest and that of the host-crop reveals that it is the overwintering population of the red pumpkin beetle which does most spectacular and serious damage because it resumes activity just when the spring cucurbit crop is coming up. Moreover, before this population awakens from winter slumber, the soil is practically free from the immature stages of this beetle. Hence, early spring is the most opportune time for dealing with this pest most effectively both for checking immediate damage and for preventing the build-up of the population. Also, the pest is most vulnerable during its adult stage. The most rational approach to its control will be as follows:

(a) Trap Crop

A few scattered plants should be grown quite early in the season so that they are in the right stage to attract the beetles as soon as they come out of their winter niches. These plants should be treated with a strong persistent insecticidal spray so that all adults attracted to these plants may die preferably so quickly as not to be able to lay eggs. Also, the soil around the roots of these plants should be treated with a strong soil insecticide so that the larvae hatching out from the eggs, if laid, may get poisoned before they enter the roots or stems.

(*b*) *Repellents*

This pest gets repelled to quite an appreciable extent even by ash. This will work all the more if some area is not treated by a repellent dust but is sprayed as a trap-crop as mentioned in the foregoing paragraph. It is also advisable to mix with the ash an insecticidal dust so that those beetles which are not repelled may get poisoned.

(*c*) *Mechanical Collection and Destruction*

This recommendation may sound archaic in the modern age but it continues to be most practical when one has to deal with a manageable area. The beetles remain very sluggish during the cool hours of early morning and it is a very useful practical proposition to shake them down in a vessel containing some kerosenized water. They can even be hand-picked. This should be particularly resorted to by those having a few plants in their kitchen-gardens. Even on the field scale, it has been possible to collect about 7,000 beetles from an area of two acres when one person worked just for one hour on three consecutive mornings.

(*d*) *Mechanical Safety*

When one has to deal with only a few seedlings in a kitchen-garden, one will be well advised just to cover each one of them under a cheap gauze cover—say, wire gauze or muslin—instead of feeling helpless against these beetles. This can help to protect the crop at the vulnerable seedling stage, which may otherwise be completely destroyed.

(*e*) *Control Measures against Immature Stages*

(*i*) As the eggs are laid on moist soil and the larvae hatch out there before entering the roots or stems, it is highly advisable that the soil around the seedlings is treated with a strong soil insecticide so that the larvae hatching out from the egg, if laid, despite the precautions mentioned above, may get poisoned before they enter the plant tissue.

(*ii*) Also, as these stages remain in soil or in the bored stems, roots, etc. it is advisable to collect and burn the remains of the cucurbit creepers after harvesting the crop and to plough up the field so as to expose the immature stages to weather and enemies. This is particularly advisable when the spring crop has been harvested and a monsoon crop is to follow. The same operation is also advisable in the case of the second crop so as to kill the beetles before they fly away and seek niches of safety. The pile of cucurbit creepers and other plant material collected in the field is quite attractive to adults seeking refuge. Hence, it is advisable to make these piles near the field when the cucurbit crop has been harvested and burn the same after a few days.

BRINJAL BORERS

(*Plate XXV*)

There are two species of caterpillar pests of the brinjal plant one of which (*Leucinodes orbonalis* Guenee) bores into the petiole and mid-ribs of large leaves, young shoots and also fruit-buds and fruits of brinjal and the other (*Euzophera perticella* Ragonot) confines its activities to the brinjal-stems only and there too it generally moves downwards, so much so that grown-up caterpillars are generally found in the lower portions of the stem, only a few inches above ground level. The former is pinkish-violet in colour, while the latter is creamy-white. The eggs are scale-like in the latter and elongate in the former.

Leucinodes sp. in the adult stage is a white moth with pink-brown markings on wings. It lays elongate eggs generally scattered on the leaf surface. Each female lays generally more than 150 eggs. The eggs hatch in about four days at 27°C and the tiny larvae immediately after hatching enter the plant tissue, the entry hole being at times too small to be easily noticeable. Hence, even healthy-looking fruits and thick stems may harbour a number of caterpillars. However, when these larvae enter the leaf petiole or young shoot, the infested portion wilts and droops. The larval period varies within wide limits, being about nine days at 27°C. If the infested tissue begins to rot, the larva leaves the same to

enter a fresh fruit or shoot. Also, the full-grown larva leaves the fruit to pupate in some comparatively dry niche. The pupal period is generally about a week and a half and adult life only a few days. The pest continues its successive overlapping generations, depending on the environmental conditions without any obligatory diapause. Different varieties of brinjal have been reported to show differential susceptibility to this pest, one set of workers reporting the varieties of long narrow fruits to be less infested than those with spherical fruits.

The *Euzophera perticella* adult is also a moth belonging to the same family Pyralidae as *Leucinodes*. Besides brinjal, this species attacks chillies, tomato and at times even potato. The moth lays eggs either singly or in batches, usually in the angles formed by the veins with the mid-rib of the young leaves although at times the eggs are also found on petioles and tender portions of the young shoot. The egg-period varies from three to 10 days although the majority of the eggs hatch in four to six days. The tiny larvae (about 2 mm in length) enter the stem or petiole tissue within a few minutes after hatching. It begins to eat up the tissue inside but its excreta can be seen coming out from the entry hole. It undergoes four or five moults before it is full-grown and the larval period varies from less than a month to about two months, depending on the environmental temperature. During this period, it feeds its way into the main stem up to a few inches above ground level. However, the species has been reported to be hibernating in the larval stage during winter, *i.e.* from November to February. Pupation takes place in a delicate dirty white or brownish cocoon, which is generally found within the tunnel wherein the larva has been feeding. At times the larva comes out of its tunnel and pupates on the plant surface or even crawls down for pupation in soil crevices. The pupal period varies from 9 to 16 days.

As regards control of the brinjal borers, the best course is to keep a watch in the early stage of the crop when the attack on the young shoot can be easily spotted and nipped in the bud. Chemical control should be resorted to only when the initial precaution has been overlooked or when infestation by sap-sucking bugs or the *Epilachna* beetle is also involved. It should also be kept in view

that insecticidal application can be expected only to check further infestation and not to kill most of the borers which have already entered the plant tissue. Special precaution is necessary not only to avoid the ratooning of the brinjal crop but also to uproot and burn the plants well before planting the new crop because the old brinjal plants harbour the borers and carry the infestation from crop to crop and season to season.

HADDA BEETLES

(*Plate XXVI*)

The beetles of the genus *Epilachna* are peculiar in the sense that they are the enemies of the farmer, while the rest of the allied genera of the family Coccinellidae (lady bird beetles) are very useful friends as they are predators and they keep a number of serious pests like aphids, scale-insects, mites etc. under very effective control. This phytophagous genus, *Epilachna*, represents a phenomenon of evolutionary reversal from the carnivorous food habit of lady bird beetles back to the herbivorous behaviour of the majority of the beetle species. The food plants of *Epilachna* mostly belong to the plant families Solanacae and Cucurbitacae and it has been reported as a pest mainly of brinjal and potato although its infestation at times becomes quite serious on other cucurbitaceous vegetables also. Their feeding habit is quite characteristic and both the adult and larval stages skeletonize the leaves which present a lace-like appearance as the green matter in-between the veins is eaten away leaving the skelton of anastomosing veins. These leaves, depending upon the area damaged, dry up and in case of severe infestation the crop presents a very unhealthy look.

The shape of these beetles is usually round with the head deeply sunk into the thorax and their colour shows a wide variation of a brownish-yellow to deep-yellow background with black spots or patches. Unless a farmer is quite careful, he can easily confuse them with the very useful genus *Coccinella*, which is of comparable size and colour variation and which is found on all crops infested with aphids and scale-insects on which it feeds.

The eggs are laid generally on the under-surface of leaves and in prominent yellow batches each of which contains up to several hundred yellow elliptical eggs glued to the leaf-surface in a vertical position. The eggs hatch in three to four days into minute larvae which have characteristic shape, the body being broad in front and narrow behind and covered with spiny structures all over. They confine their feeding activities generally to the under-surface of leaves. The larval period varies from 12 to 18 days during which there are three larval instars. The pupation takes place on the leaf-surface. At that time the full-grown larva attaches the last segment of its abdomen to the leaf-surface by means of a sticky secretion and the pupa is formed within the last larval skin which splits on the dorsal side. The pupal period varies from three to six days after which the adults emerge. The adults are also quite voracious feeders and they feed both on the upper and lower surfaces of the leaf and their longevity varies from less than a month to more than two months.

As regards the control of this pest, its infestation can be nipped in the bud, particularly if the area is small by collecting and destroying the egg-masses which can be easily spotted. Also the larvae and adults can be shaken down in a pail of kerosenized water early in the morning. If the acreage is large, chemical control by means of a persistent contact and stomach poison can be resorted to with due precautions.

CHAPTER IX

PESTS OF FIBRE CROPS

THERE are four important fibre crops in India, viz. cotton (*Gossypium* spp.), jute (*Corchorus* spp.), sunnhemp (*Crotalaria juncea* Linnaeus) and mestra (*Hibiscus cannabinus* Linnaeus). It is, however, proposed here to describe as examples only a few very important pests of the first two crops.

COTTON PESTS

The pest spectrum of the cotton crop is quite complex; more than 130 species of insects are reported to inflict damage on the cotton plant at one stage or another. Hence, the control of the cotton pests is equally complex. Fortunately only some of these are of economic importance and are categorised as serious pests. Results of control experiments reported from different regions have been rather erratic, the various probable reasons for such a situation being (*a*) comparatively greater multiplicity of pest species several of which often coexist, (*b*) several of the pest species have each several natural enemies, so that the good work done by a pesticide is often offset by a reduction in the parasite and predator populations, and (*c*) the physical nature of the grown-up cotton crop is such that its micro-climate is very favourable to pest development and proper coverage of the plants with a pesticide is quite difficult. It is, however, proposed to describe below only two of the internal feeders and two of the external feeders.

SPOTTED BOLLWORMS

(Plate XXVII)

There are at least three species of the spotted bollworms of cotton but two of them, *Earias insulana* and *Earias vitella*, are serious pests. These noctuid moths have been described under many different names during the 19th century, probably the first being

Tortrix insulana by Boisduval (1833) but the present names have now been stable for quite some time. Also, these insects are very widely distributed. For example, the world distribution of *E. insulana* is reported to include Spain, Sicily, Crete, Syria, Palestine, Egypt, India, Burma, Malagasy and Australia. Besides cotton, these pests attack a number of other plants of the family Malvaceae among which the vegetable lady's finger or okra (*Abelmoschus esculentus*), is of great economic importance. In some countries it has been reported to feed on maize as well.

The larval stages constitute the destructive phase of the pest. This stage bores the stem portion of young seedlings and shoot and later eats into young squares as well as buds and bolls. The larvae undergo four or five moults. Their main characteristic is that their body-surface is irregularly spotted and spiny. Hence, in some countries, they are called spiny bollworms and in others spotted bollworms. Even when full-grown, the larvae are less than 2 cm.

The adult stages are medium-sized moths, the length being about 1 cm and the wing-span about 2 cm. The body colour is generally some shade of bright-green and the abdomen is silvery in appearance. The wings have three transverse lines of varying distinctness. The duration of the various stages varies within very wide limits, depending on the temperature and humidity of environment. Adult longevity varies from less than a week to more than two months. The moths lay eggs generally singly scattered over fresh leaves, fresh squares, etc. The eggs hatch in less than three to more than 10 days. The just-hatched larva roams about on the plant surface for a very short period of about half an hour and then begins to bore into the plant tissue. The larval period varies from about a week to more than two months. Pupation takes place generally in fallen material, on plant surfaces and in cracks and crevices of the soil. Before pupation, however, the larva spins a dirty white silken cocoon. The pupal period lasts from a few days to more than two months.

There are a number of natural enemies of the pest. Insect parasites attack the eggs, larvae and pupae of the spotted bollworm. These biotic agents obviously exercise quite an effective

check on the pest; all the same, it often assumes serious proportions in various cotton-growing regions.

The rational approaches regarding the control of this pest are:

(*a*) *Destruction of Plants which Harbour the Pest during the Off-season for Cotton*

This pest does not undergo hibernation although its activities are very much affected by weather conditions. It is carried over from one crop of cotton to the next either by the sprouts from the cotton stalks left after harvest or by alternate host plants. Hence, it is advisable to uproot and burn the cotton stalks soon after harvest and to arrange for mass-scale destruction of wild alternate food plants in large compact areas. Special care should be taken that vegetable crop of lady's finger is kept completely free from the infestation of this pest, particularly when grown in off-season; otherwise not only will the vegetable crop suffer but the following cotton crop also will be adversely affected.

(*b*) *Collection and Destruction of Infested Material*

When infestation starts in a young cotton crop, it is often possible to spot out from a distance the plants, the tender shoots of which are infested by this pest. Such infested shoots wilt and droop and they can be easily clipped and burnt or buried. Similarly, infested squares and bolls drop from the plant and they can be collected and destroyed. Also, pupation takes place in fallen plant material which can be collected and burnt. Of course, in order to ensure proper dividends this item has to be carried out in a concerted manner in large compact blocks.

(*c*) For chemical control, an insecticide with a good persistent contact effect should be selected. Two precautions are necessary to ensure success: (*i*) the insecticidal applications should be so timed as to coincide with the peak of the hatching of eggs, so that the just-hatched larvae may get the fatal dose before entering the plant tissue, and (*ii*) the parasite activity in the field should be carefully assessed before the insecticidal application. Often the chemical control has been responsible for nullifying whatever good work was

being done by parasites and predators and annihilating their population.

PINK BOLLWORM

(*Pectinophora gossypiella* Saunders)

(*Plate XXVIII*)

The pink bollworm is a very widely distributed and probably the most serious cotton pest on a world basis. Its original home is considered to be the South-Asian region wherefrom it has spread, presumably through commerce, to practically all the cotton-growing areas of the world. All the same, the seriousness of this pest in this region has been accentuated by the introduction of exotic varieties of cotton. Thus, the American cottons in this country are damaged much more by the pink bollworm than the indigenous varieties which have obviously undergone natural selection against pink bollworm infestation. There are various examples of exotic pests becoming serious in the country into which they are introduced; a large number of agricultural pests in the U.S.A. come under this category. The cases of pink bollworm and a few other pests of cotton in India afford interesting earlier examples wherein the introduction of exotic varieties led to the accentuation of the seriousness of indigenous pests. Many more such examples have come to the forefront in India during recent years due to large-scale introduction of exotic germ-plasm of various crop plants.

The scientific name of this pest has undergone a lot of change in its generic component from *Depressaria*, *Gelechia* and *Platyedra* to *Pectinophora* but the specific component *gossypiella* has remained unchanged. The common name is obviously due to the distinctly pink colour of the harmful larval stage but it will be wrong to suppose that any pink larva associated with cotton will be this pink bollworm. At least two other pink caterpillars are known to be associated with cotton, though their economic significance is negligible as compared to this pest. Also, the pink bollworm is not pink in its earlier stages and even in the later stages under certain circumstances. Though the pink bollworm is a

specific pest of cotton, it has also a few alternate wild hosts in the family Malvaceae.

The pink bollworm larvae do most spectacular damage to mature cotton bolls in which they enter as tiny just-hatched larvae, their entry holes get blocked and they remain inside devouring both seed and fibre forming tissues. The infestation at times is so severe that up to 10 caterpillars are found in each boll and 75 to 100 per cent bolls are found infested. If the attacked bolls are not shed and remain on the plant till they open after ripening, the cotton fibre which escapes damage gets at least stained and even the oil content of the seed, ginning percentage and the spinning qualities of the fibre are adversely affected. Also, these larvae may attack young bolls which invariably fall down. They also bore into the flower buds and flowers. Like the spotted bollworm, the pink bollworm also has a number of alternate hosts mainly in the family Malvaceae.

The adults of the pink bollworm are small moths of dark fuscous brown colour and about 1 cm in body length. The moths are comparatively quite long-lived and the female particularly has been reported to live up to about two months under certain conditions. They are active during the night when they lay flattish scale-like whitish eggs singly on various parts of the young shoot. However, half-developed bolls are preferred when available. The egg period varies from three to seven days and the just-hatched larva is colourless and about 1 mm in length. It bores into the boll where it begins to feed on seed and when one seed is consumed, it passes on to the next. It also moves from one locule to another. The entry hole gets quickly healed up, so much so that often it is not quite easy to distinguish an infested boll from an uninfested one. This fact rules out the feasibility of collecting attacked bolls from the plant as a possible method of control.

The characteristic pink colour of the larva develops as a rule during the last two instars; also, those feeding on open flowers remain creamish in colour. The larvae undergo generally only three moults, and the larval period depends on two distinct types of life-cycles which this species generally undergoes and which are referred to as short-life cycle and long-life cycle. The short-life cycle is typical of any lepidopterous life-cycle extending for about

a month or more depending on environmental temperature but the long-life cycle includes a very prolonged period of larval hibernation which may extend even up to two years, according to some workers. The interesting point is that at certain times of the year, particularly late in fall, two types of larvae are found in a mixed population—one type pupates in the normal manner, while the other type makes preparations for prolonged hibernation. The larva scoopes and binds together around itself generally two but at times more than two seeds with the help of its self-produced silk and then enters the resting-stage in the hibernaculum prepared between these double-seeds and lined with silk. This resting-stage in double seeds is very largely responsible for the seriousness of this pest. In this stage not only is the insect able to bridge over long periods of unfavourable weather but it can also be carried over long distances. It is this stage which has been responsible for the universal distribution of the pink bollworm in the cotton-growing regions of the world. Although it is a field pest it is carried over like storage pests from place to place through commercial channels along with the movement of cotton-seed. If this double-seed is sown along with healthy seeds, the resting larva comes out of its hibernaculum and makes a tunnel up to the surface and then goes down to pupate. Thus, the moths after emergence are able to come out and infest the resulting crop. Also, as the females are long-lived, they can await the development of the crop for egg-laying. However, the site of pupation varies within wide limits. The pupae may be found within the boll, amongst the lint, inside the seed, in brackets, soil cracks and crevices or within the so-called double seeds. The size of the pupae is generally less than a centimetre and the pupal period varies from one to three weeks.

There are a large number of natural enemies of the pest including some bug predators on the egg-stage and about half a dozen insect parasites of the larval and pupal stages.

The most important item of control measures recommended against this pest is the large scale destruction of the resting-stages of the larvae in the double-seeds of cotton. This is the most feasible and practical step. The destruction of this stage can and should be carried out as early as possible after cotton harvest and at any rate much earlier than the advent of suitable weather or the

distribution of cotton seed. The destruction can be brought about by fumigation or heating of the cotton seed or even by exposing it to hot sun. This is a very sure method of control, provided it is ensured that no seed is left untreated in large compact areas. Efficient execution is the most important precaution necessary for the success of this method. Another additional precaution is the removal and utilisation of the cotton stalks soon after harvest or at any rate much earlier than the sowing of the next cotton crop, so that the carry-over of the infestation from the previous crop to the succeeding crop is avoided.

The control measures recommended for operations during the crop period are: (*a*) collection and destruction of infested flowers, flower buds, etc. along with the shoots infested by the spotted bollworm quite early in the season, and (*b*) application of contact insecticides, particularly directed against first-stage larvae and adults before they lay eggs.

COTTON JASSID

[*Amrasca biguttula biguttula* (Ishida)]

The cotton jassid has been posing a very serious problem to cotton growers in India ever since the introduction of exotic varieties of this crop. The failure of a variety of exotic cotton in large areas of the Punjab during 1913-14 was mainly attributed to jassid attack. Since then the seriousness of this pest became a bottleneck in cotton cultivation in several parts of India and some of the best cotton varieties had to be discarded because they could not withstand jassid attack.

The jassids are popularly known as leaf-hoppers, particularly because their activities are mostly confined to the leaf surface and their legs are specially developed and modified for hopping like those of locusts and grasshoppers. They are generally very active insects and at even the slightest disturbance they dodgingly dart away by a very characteristic movement. Hence, they have also been referred to as dodgers and sharp-shooters by cotton-growers in the U.S.A. Also, the jassids' flight is of a curious whirling type which is difficult to follow. Although generally they fly only a few metres before settling again, some species of leaf-hoppers have been reported to fly for long distances in great swarms. These

insects are active at night and are attracted to light in very large numbers.

There are many species of jassid pests in India but the genus which has attracted most attention is *Empoasca* Walsh. At least 14 species of *Empoasca* are known to attack cotton in different parts of the world and also about a dozen species of this genus are known from India. Of these, *E. devastans*[1] Dist. is economically by far the most important in India. It is a small insect, the various nymphal stages of which vary from less than a millimetre to about 3 mm. Its adult stage is subject to seasonal changes in colour.

All the nymphal stages as well as the adults inflict the same type of damage. Like other bugs, they suck out the cell-sap from the plant tissue. Moreover, it is also believed that during the process of desapping the plant, they also inject a toxin into the plant issue, resulting into what is commonly described as hopperburn. Even in resistant varieties of cotton, jassid attack leads to the wilting of the leaf followed by the drying-up of the apex and periphery of the leaf which becomes brown and necrotic. In susceptible varieties, on the other hand, the jassid attack results in general mottling accompanied by the curling of the entire lamina with brown necrotic patches. Thus, the entire photosynthetic activity of the plant is very seriously interfered with. Hence, it is no wonder that the cotton jassid is considered to be a very harmful pest. What is surprising is that this pest is not so serious in the whole of the U.S.A. as it has been in India particularly on American cottons. Jassids are generally pests of first importance in a number of cotton-growing regions of Africa such as Tanzania, Ethiopia, and Eritrea.

The pest has a number of alternate hosts mostly belonging to the families Malvaceae and Solonaceae.

The eggs are usually inserted full-length into the spongy parenchymatous tissue between the vascular bundles and the epidermis and they hatch within a period varying from about four to eleven days. The nymphs moult five times and the whole life-cycle is completed in a period which varies from about two weeks to more than a month and a half, depending on environmental temperature

[1]Now known as *Amrasca biguttula biguttula.*

and humidity to which this pest is very responsive. As many as 11 generations have been recorded in the Punjab.

Detailed studies on the habits and behaviour of the cotton jassid have revealed that it is quite discriminating in its attack on different varieties of cotton. This has led to a lot of experimentation on developing resistant varieties and on the criteria on which the jassid resistance is likely to depend. Effort has been made to correlate jassid resistance with factors like hairiness of the leaves and toughness of the leaf-veins as these factors are likely to hinder the processes of both feeding and oviposition; but the results on the whole have not been consistent and convincing.

Till very recently, it was a surprise that no natural enemies of this pest were on record but during the last few years about half a dozen egg parasites have been recorded at I.A.R.I. But for this natural check, probably the havoc caused by this pest would have been much greater.

Till the advent of modern synthetic insecticides, the control of the cotton jassid was practically an unsolved problem. Now, however, there are a number of very good systemic and contact insecticides which can keep cotton crop practically free from jassid attack. In fact, the present position is that an insecticidal application used for any other pest like the spotted and pink bollworms will automatically check the cotton jassid. Also, a number of experiments on the control of internal feeders like the bollworms have given higher yields without significantly reducing the population of those internal-feeders and the yield increases have been due to the control of external pests like the cotton jassids.

It is particularly interesting to note that while a pest like the pink bollworm lays eggs on the surface of the plant, the young ones feed inside the plant tissue; the jassid acts in the opposite manner—it lays eggs inside the plant tissue but the young ones and adults remain on the plant surface. This difference in behaviour has made all the difference in the control of these two types of pests.

COTTON WHITEFLY

(*Bemisia tabaci* Gennadius)

(*Plate XXIX*)

The common name whitefly is applied to a group of small

(about a millimetre or so) sucking insects which it is generally difficult to distinguish from scale-insects except in the adult stage in which they have a pair of floury wings which are usually white, with a few veins and as if dusted with wax; hence, they are also referred to as mealy wings. The eggs are usually attached to the leaf surface by a very short stalk. The young larvae hatching out from these eggs are quite active with normal functional legs and antennae and they move about in search of a suitable place where they can settle down to feed for the rest of their brief existence. Soon thereafter, the first-stage larvae moult and become legless, scale-like, flattened and pressed to the leaf surface. Also, their body gets covered with a kind of wax secreted by them. They further undergo two moults and then pupate, followed by the emergence of the imago. Both the adults and their immature stages, except the eggs and the pupa in its later period of existence, suck the plant sap and thus devitalize the plant.

From the pure scientific point of view, this group of insects is very interesting because among the whole order of bugs, only this group undergoes some sort of pupation. Thus, in this respect, it stands between a large group of insects which pupate and those in which there is no pupal stage. The pupa of whiteflies is of a rather rudimentary type. During the first part of this instar, it sucks its food like the larval stage but later on it becomes passive.

The cotton whitefly (*Bemisia tabaci* Gennadius) is known to infest about 50 different species of plants but it becomes quite a serious pest of cotton in certain regions of the country. The infestation by this pest adversely affects the physiology of the cotton plant at all stages of its growth. The vegetative growth is retarded and boll-formation is seriously hampered. Also, the shedding of the bolls is accentuated and proper opening of the bolls is interfered with. Besides inflicting this direct damage, the pest produces honeydew which spreads on the leaf and leads to mould development which gives a very unhealthy blackish appearance to the crop and adversely affects photosynthesis. In all these ways, both the quantity and the quality of cotton suffer due to whitefly infestation. This pest is also known to act as a vector of some virus diseases particularly in the tobacco crop.

A single female of this species lays about 70 eggs which hatch

in one to four weeks' time. The insect can often breed parthenogenetically, i.e. without mating between the male and the female. The eggs are as usual stalked and light yellow in the beginning but turn brown later on. The freshly-hatched nymph has a number of bristles jutting out from the margin of its oval flat body.

As the species is polyphagous, it goes on migrating from crop to crop in different seasons throughout the year and there is no difficulty in tiding over the off-season as one or the other host plants will always be available for these flies to feed and breed. Among the cultivated crops, it attacks cotton, rape, radish, watermelon, cucumber, chillies, brinjal, tomato, potato, tobacco, etc. Also, there are a number of wild host plants.

The population of the cotton whitefly is quite susceptible to changes in the environment of the cotton crop and also in the physiology and nutritional status of the cotton plant. High temperature and low humidity are reported to be conducive to the multiplication of this pest. In fact, the oviposition activities of the adults of the whitefly are reported to be optimum above 33°C. Also, the incidence of this species has been found to be positively correlated with the pH of the cell sap of the cotton plant.

A chalcid parasite attacks the older nymphs and pupae and the parasitization is at times more than 30 per cent. Also, there are a few predators like some species of Chrysopa and Coccinellids which feed on different stages of the pest.

Several of the modern contact insecticides are quite effective in the control of the whitefly menace. In fact, often the insecticidal applications for the control of bollworms, etc. automatically control the whitefly as well.

Control Schedule for Cotton Pests

For formulating a rational control schedule, the cotton pest spectrum, despite all its complexity, should be divided into two broad groups (*a*) the internal feeders like bollworms, and (*b*) those that remain on the plant surface like jassids, aphids, whiteflies, etc. Subject to their time of appearance which differs from place to place the pesticides applied against the internal-feeders should

control the external pests as well. Keeping these general points in view, a rational schedule should be somewhat on the following lines:

(*a*) Soil treatment by persistent insecticides particularly in areas where damage done by termites, weevil grubs, etc. is serious year after year.

(*b*) Early dusting or spraying of the crop as soon as pests like jassids, whiteflies, aphids, etc. begin their appearance. This treatment will also nip in the bud the infestation by bollworms.

(*c*) If pests like jassids, aphids. etc. do not appear and there are signs of bollworm attack in tender shoots which can be easily located, then a mechanical control campaign should be organized against this pest instead of item (*b*) above.

(*d*) Treatment of the cotton crop by a persistent contact insecticide applied in the form of a thick fog which may penetrate the thick foliage of the cotton crop and leave a persistent insecticidal film strong enough to fatally poison the just-hatched larvae of bollworms before they enter the plant tissue. These applications should be properly timed by means of a biometer so as to coincide with the period of larval hatching. These applications will control aphids, jassids, etc.

(*e*) Also, in-between the treatments described under (*d*) a suitable insecticidal formulation should be applied through irrigation water, so that the pests harboured in fallen leaves, bolls, etc. may be killed.

(*f*) Chemical control should be suitably integrated with biological control whenever biological control agents are available.

Jute Pests

During the first decade of the present century, jute crop was considered to be comparatively immune to pests but an authentic review made around 1960 lists as many as 29 species of jute pests. Some of these pests, viz. the jute semi-looper, the jute apion and the jute stem-girdler are considered to be particularly serious needing description in some detail. The so-called indigo caterpillar (*Spodoptera exigua* Hiibner) is also quite serious at times.

JUTE SEMI-LOOPER

[*Anomis sabulifera*.(Guenee)]

(*Plate XXX*)

This pest has a wide distribution right from Sri Lanka in the south, Burma in the east and through India up to Africa in the west. It is considered to be the most serious pest of jute foliage. The infestation is said to come about in three successive waves of which the middle one is the most damaging. The apical buds of the plant are most vulnerable and the intensity of infestation tends to vary inversely with the age of the foliage. Because of the green colour of the pest, it is difficult to detect it against the green background of the leaf but the holes and marginal cuts on leaves give a characteristic appearance to the foliage and presence of these symptoms is a sure indication of its infestation.

It is the green caterpillar which was earlier referred to as *Cosmophila sabulifera* Guenee and is now called *Anomis subulifera*. It is called a semi-looper because all the five pairs of its sucker-feet are not well-developed, so that when it moves it humps its back into an arch like a true looper caterpillar. In its look, it is an ordinary caterpillar but its gait is like a looper.

The pest hibernates during winter in pupal stage and the moths emerge with the onset of moist warm weather. These moths are not seen during the day when they hide away and they come out and fly about only after sunset. If the jute crop is available, the moths lay eggs on the jute plant singly particularly on the underside of the young leaves. The egg looks very much like a tiny drop of water on the leaf. There may be several such eggs on each leaf. A single moth can lay more than 150 eggs. The egg-period lasts for about two days after which a small green caterpillar hatches out. This tiny creature has only three pairs of sucker-feet but subsequently a fourth pair also develops; the fifth pair is never well-developed and it is in this region that a hump is formed during movement. The caterpillar is green although the head is slightly yellowish and each segment bears short hairs on small white-ringed black papillae. The full-grown larva is about 4 cms

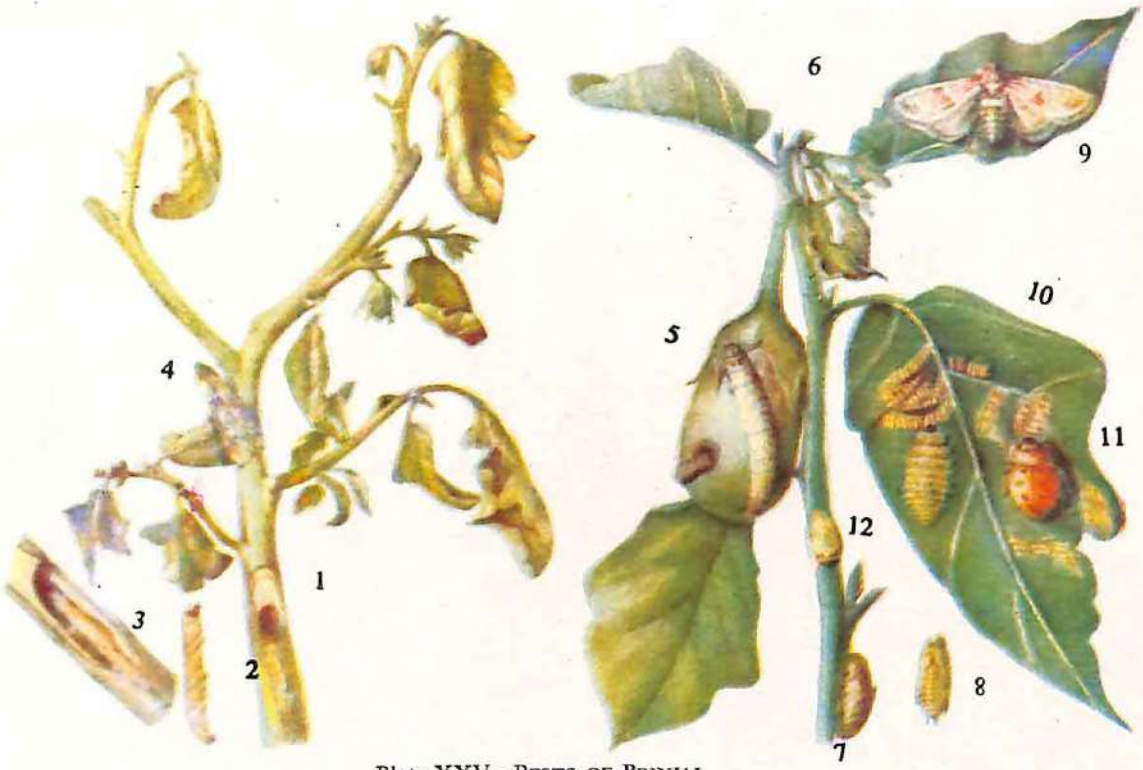


Plate XXV—PESTS OF BRINJAL

Euzophera perticella : 1. Larva in its burrow in the stem 2. Larva removed from burrow 3. Pupa in stem 4. Moth in resting attitude 5. *Leucinodes orbonalis :* larva 6. Effect of boring in stem causing withered top-shoot 7. Cocoon 8. Pupa 9. Moth 10. *Epilachna :* egg-mass on leaf 11. Beetle, eggs and larva 12. Pupa.

(*Some South Indian Insects*, Plate XXX, p. 428)

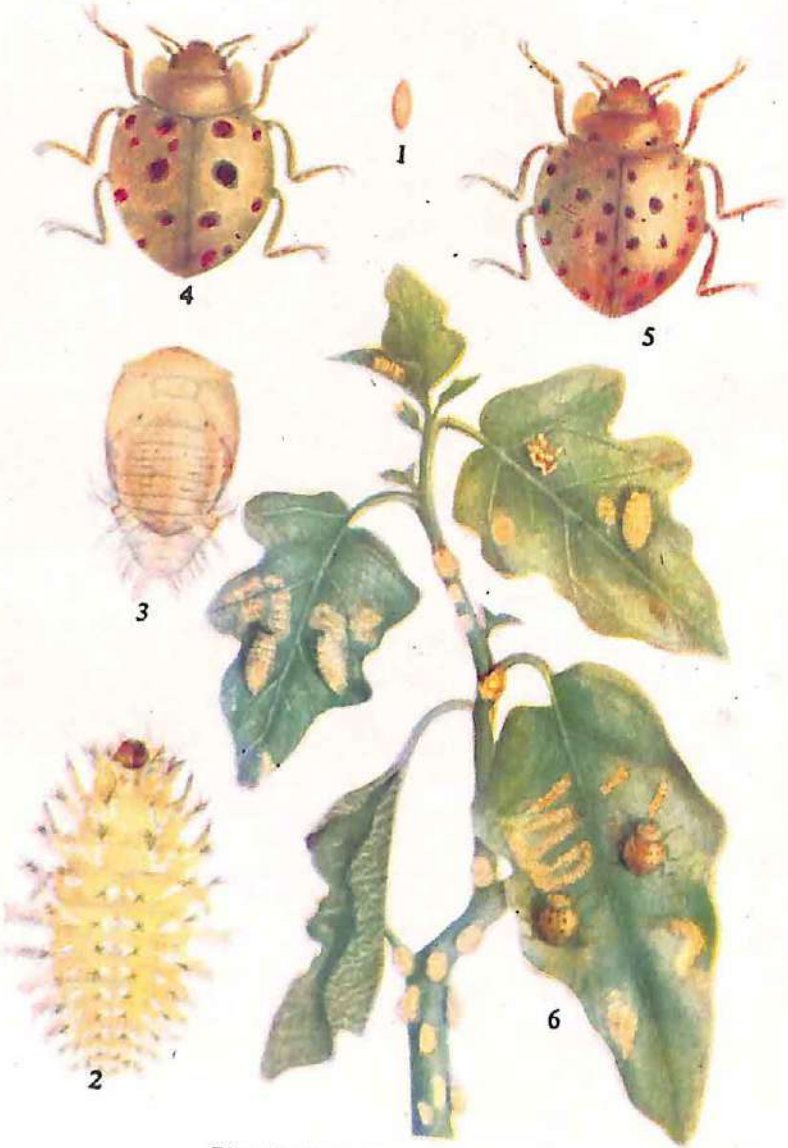


Plate XXVI—HADDA BEETLE

Epilachna dodecastigma : 1. Egg 2. Larva 3. Pupa 4. Beetle 5. *Epilachna 28-punctata* : beetle 6. Beetles (both species) on plant, showing eggs, larvae, pupae, adults and damage done.

(*Some South Indian Insects*, Plate VI, p. 292)

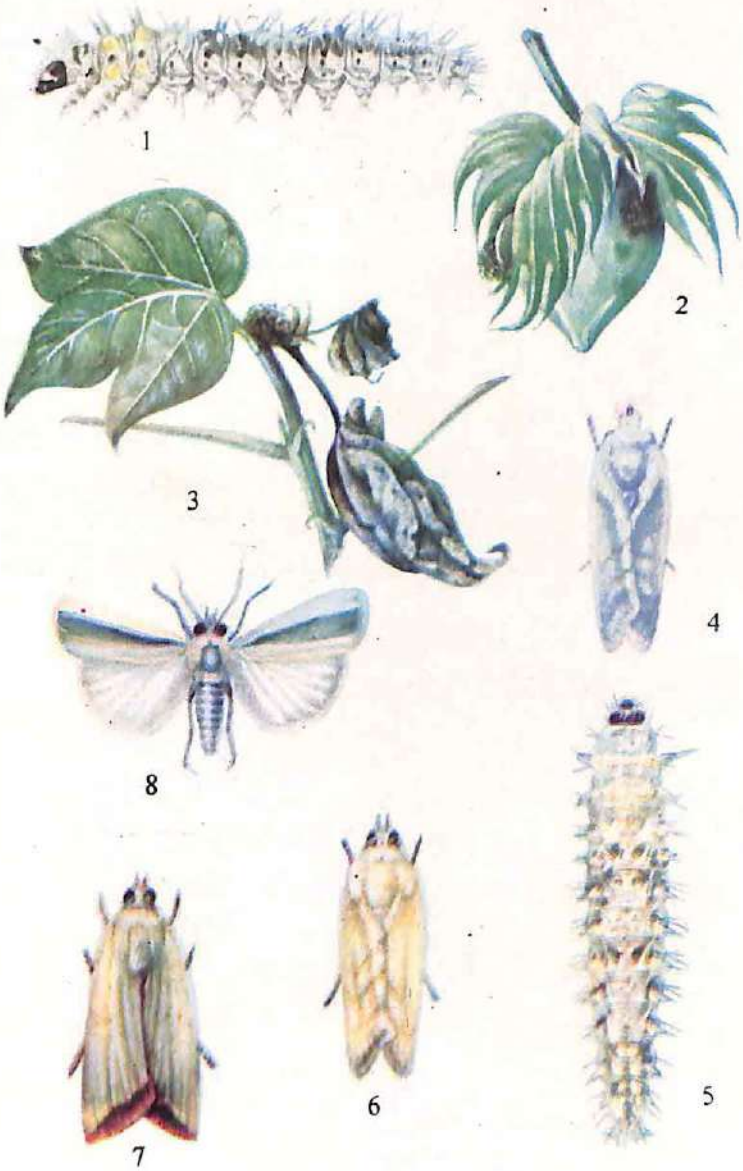


Plate XXVII—SPOTTED BOLLWORM

1. Larva of *Earias insulana*, lateral view 2. Attacked boll 3. Attacked shoot of cotton 4. *E. insulana*, 5. Larva of *E. insulana*, dorsal view 6. *E. insulana*, yellow variety 7. *E. cupreoviridis* 8. *E. vitella*

(*Indian Insect Life*, p. 456)

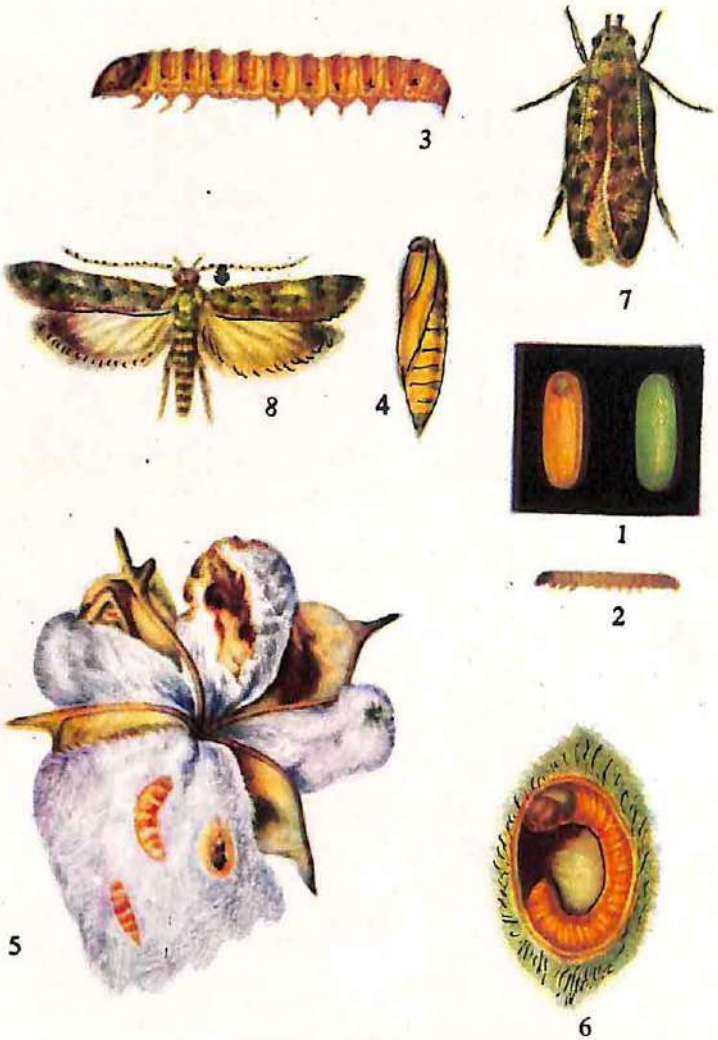


Plate XXVIII—PINK BOLLWORM

1. Eggs 2. Young larva. 3. Full-grown larva 4. Pupa 5. Infested cotton boll 6. Larva inside cotton seed 7 & 8. Moths.

(*Some South Indian Insects*, Plate XLII, p. 454)

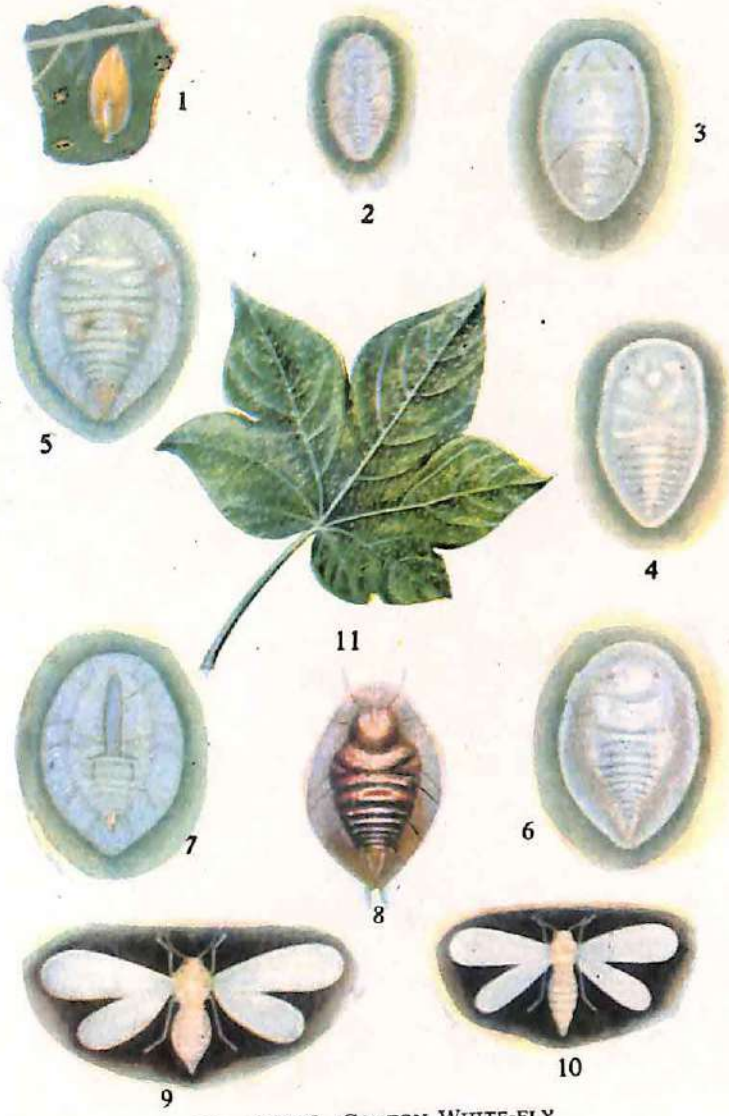


Plate XXIX—COTTON WHITE-FLY

1. Egg 2. Larva 1st instar 3. Larva 2nd instar 4. Larva 3rd instar 5. Larva 4th instar 6. Pupa 7. Empty pupal case 8. Parasitized puparium 9. Male 10. Female 11. Leaf infested with larvae and puparia.

(*Pusa Bulletin*, No. 196, Plate I)

Plate XXX—JUTE SEMILOOPER

1 & 2. Larval stages on twig of host plant 3. Pupae in soil 4. Pupa 5. Adult in resting posture 6 & 7. Adults (set).

(Entomology Division Collection I.A.R.I.)

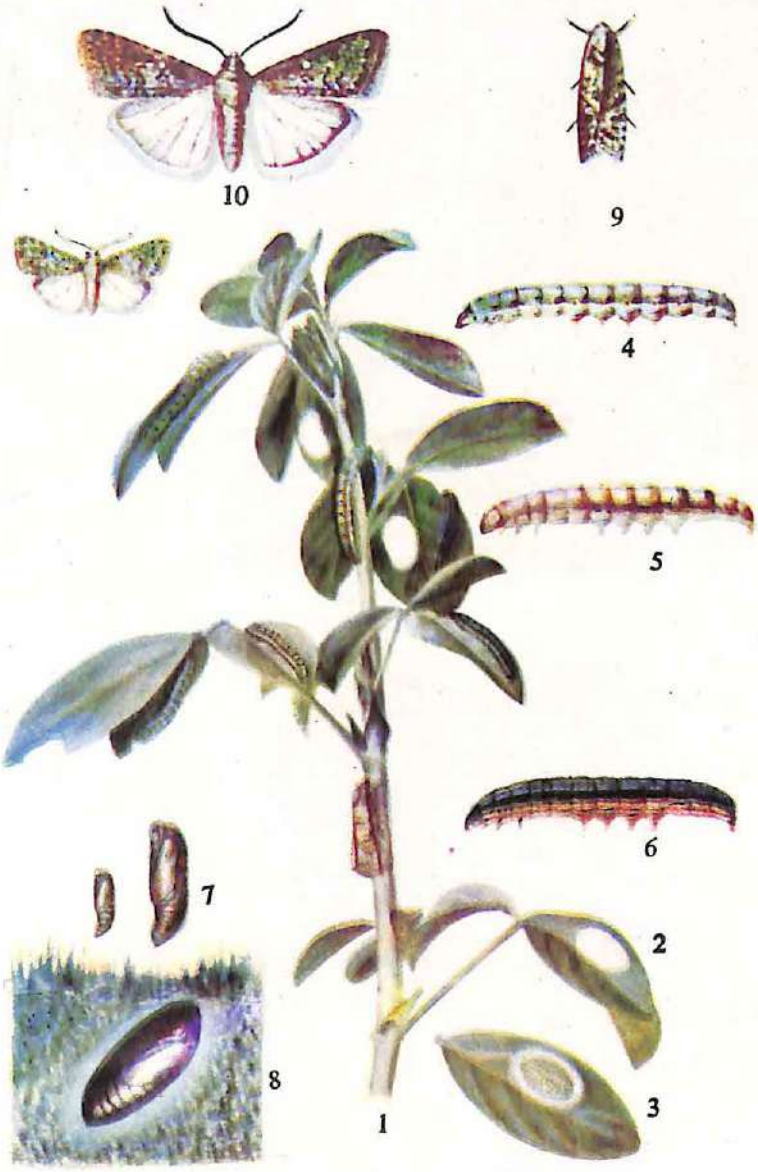


Plate XXXII—SPODOPTERA

1. Infested twig 2. Egg-mass-covered with hairs 3. Egg-mass exposed 4—6. Larval stages 7. Pupal stage 8. Pupal stage in the earth 9. Adult in resting posture 10. Adult (set).

(Entomology Division Collection, I.A.R.I.)

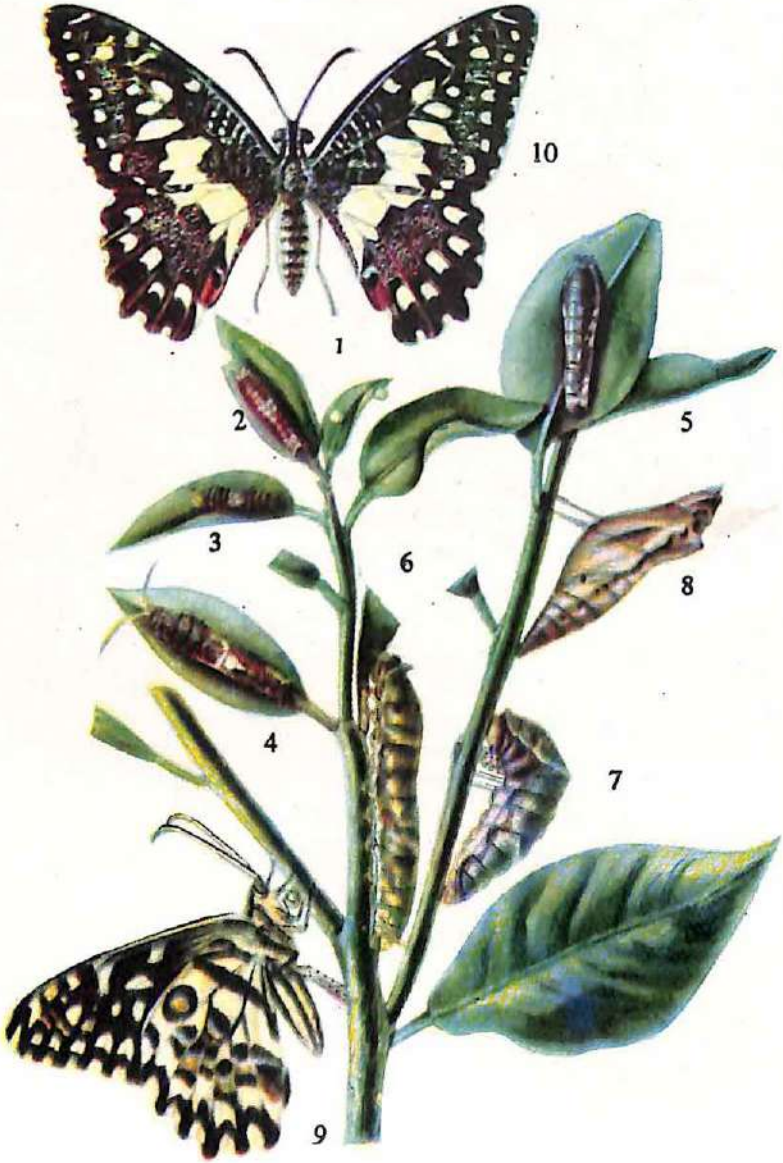


Plate XXXIV—LEMON BUTTERFLY

1. Egg laid on leaf 2—6. Larvae in various stadia 7. Larva suspended for pupation 8. Pupa 9 & 10. Butterfly.

(*Some South Indian Insects*, Plate XXV)

long and it attains this size after five moults during a period of about 2½ weeks. Before the last moult the larva generally goes down to the soil where it usually pupates, although pupae have been observed outside the soil also. Pupation may also occur on the plant itself. In case of pupae which are not hibernating, the pupal period lasts for only a week or so after which the moths emerge and begin to produce the next generation. The whole life-cycle takes about a month.

It will be seen from the account given above, that the study of the life-history of the pest has not revealed any specially vulnerable spot which can be exploited for its control. The eggs are laid singly on the under-surface of leaves and cannot be easily collected ; the larvae are not gregarious and, therefore, their hand-picking is tedious ; the pupae pupate in the soil and are difficult to trace from the control angle and the moths are nocturnal and hence not easy to catch. The only somewhat weak point is that the pest hibernates as pupa in the soil and when the crop is harvested leaving stumps in the field the hibernating population is safe ; but if the field is thoroughly ploughed up and margins kept clean, the mortality of the hibernating population is high. However, under these circumstances the only rational approach against this pest is through chemical control, utilising highly persistent insecticides which act both as contact and as stomach poison at the time when leaf damage is observed.

STEM-GIRDLER

This pest *Nupserha bicolor postbrunnea* Dutt (Lammidae : Coleoptera) was first reported to be serious on jute crops only about two decades ago, i.e. since the post-partition intensification of jute cultivation in India during which there was a rapid extension of jute cultivation from 0.652 million acres in 1947 to 1.952 million acres in 1951 in the Indian Union. It is surmised that the pest was originally confined to a number of rather less important alternate hosts among which *Sesbania aegyptiaca* (*Dhaincha*) is said to have been the main source from which the pest began to attack the jute crop. It is further interesting to note that this pest has so far developed a liking only for one species of jute *Corchorus olitorius* which

it is able to select discreetly, even if the plant population of this species constitutes only 2 per cent in a crop of the other species of jute *C. capsularis* which the pest equally discreetly avoids. This is a very spectacular case of strict selection made by the adult stage prior to oviposition. The *capsularis* species is not only resistant but also unacceptable for oviposition. This is true even if the larval stage has been artificially fed on *capsularis* diet. A yet another interesting aspect of the pest is that it does not cause so much damage to the jute crop by the feeding activities of the adult or immature stages as it does during its activities preparatory to oviposition.

The adult beetle stage feeds on leaf-veins. The female while preparing for laying eggs cuts, with the help of its sharp mandibles, two rings around the stem so that the distance between these two rings is generally 1 to 1.4 cm and thereafter it makes, with its mandibles again, a slit on the stem between these two rings. The depth of this slit reaches down to the pith level where a single egg is deposited. By this time real damage to the attacked stem has already been done because the portion of the stem above the lower ring in due course withers to ultimate death. The average number of eggs laid per female is 35 ; hence, the same number of jute-stems are on an average damaged by one female in the course of two to three weeks. Egg-laying starts about eight to ten days after emergence and there is an interval of four to 48 hours between two subsequent egg-layings.

The ovipositing female makes a fairly judicious selection of the thickness of the jute-stem before girdling and laying the egg. The diameter most preferred lies between 2 mm and 4 mm. This diamater is available at different heights of the jute-stem, depending on the age of the crop. As it is the length of the fibre above the oviposition-site that is lost as a result of the pest attack, the percentage of the fibre length lost is highest in young plants and lowest in full-grown plants. This percentage loss has been reported to vary from about 30 in young plants to only about 6 in grown-up plants. Further, the diameter-range selected in jute plant is different from that in *Sesbania* sp. Critical studies have, however, shown that the constant factor is the ratio between the length of the mandible of the beetle and the depth of the extra-modulary tissue which the female adult has to girdle through.

Specially-designed experiments have indicated that the female girdles the two rings on the stem for the special purpose of arresting the flow of the plant sap and thus creating suitable conditions for the development of the egg. It has been shown under experiment conditions that if eggs are transferred into artificial slits made into the stem without making the girdles above and below the slit, then these eggs are often crushed by the callous tissues developing in the region of the slit. This, however, does not happen on a large scale if the plants are already stunted and with much less moisture content than in succulent quick-growing stems.

The egg is yellowish in colour, about 1.5 mm in length and about 0.5 mm in diameter. The incubation period is three to four days at about 40°C. On hatching, the larvae travel downwards along the central hollow area, resulting from the disintegration of the pith. This activity has no appreciable adverse effect ; also, the larva neither enters the branches if any nor makes any horizontal tunnel so as to spoil the jute fibre. The total larval period during the normal jute season varies between 30 and 50 days but at the advent of winter the larva enters the diapause phase. Before pupation or diapause, the larva makes a pupal chamber within the hollow of the stem. Also, before entering diapause the larva almost cuts out this small portion of the stem within which it encases itself. The two ends of the pupal chamber are plugged with wooden chips. This piece of the stem drops down and also it floats up and saves the larva from getting drowned when jute plants are put under water for retting after harvest. The mature larva measures about 1.4 cm on an average but it gradually shrinks to half this length before undergoing diapause. The diapause phase lasts till a favourable combination of environmental factors is obtained during the following summer but under unfavourable conditions it may last for several years. The pupa closely resembles the adult beetle in form and size. It measures about 0.8 cm. The emergence of the adult largely depends on the time and amount of rainfall.

As regards control, the two rational approaches can be: (*a*) growing of *capsularis* species in areas where the stem-girdler is the chief pest, and (*b*) treatment of the crop with a persistent insecticide with contact and stomach poison effect soon after adult emergence starts so that they can be killed before their oviposition

starts about eight to ten days after their emergence which itself follows frequent and sufficient rainfall.

JUTE STEM WEEVIL

(*Apion corchori* Marshall)

(*Plate XXXI*)

This stem-borer is a weevil (snouted beetle) which is also commonly called the jute Apion. It damages the quality of the jute fibre. The female weevil which is a very minute insect bores a hole by means of its rostrum in the jute stem generally in the apical region and then lays an egg therein. At times, there are a number of surrounding holes but only one of them contains an egg indicating that other holes were not found suitable for oviposition. The base of the petiole is generally the favoured site of oviposition. A single female has been observed to lay up to 675 eggs during a period of 124 days. This process itself adversely affects the development of fibre near the place of injury. Further, the larva, on hatching, begins to feed on the surrounding tissues and generally damages the fibre. Where such damage is excessive, the shoot above this point withers and a number of side branches are formed. Such plants yield short fibres of poor quality. When the attack takes place at the seedling stage, often the whole plant succumbs. At times, pods are also infested and damaged. The quality of the jute fibre also deteriorates very much due to a number of reaction changes brought about at the site of injury. A mucilaginous substance oozes out of the site of damage and it firmly cements the adjacent tissues with the insect's excreta into a hard structure which is very resistant to the retting process. Further, a kind of corky tissue develops round the wound which actually represents the plant's reaction to localize the injury and during this process also the fibres get cemented together, with a good deal of surrounding tissue, into a kind of knot. Later in the season the infestation shifts from the apical portion to the basal region where the whole of the bark is found riddled by the grubs, resulting in a hard compact mass with the bark sticking to the fibre. All these deformities resist retting so much that even after prolonged processing when the fibres are washed, they are found to be either

actually knotty or at least specky. Very much unlike the stem-girdler this pest prefers *capsularis* to *olitorius*.

The egg-period during the optimum season may be as short as three days. On an average an egg measures 0.43 mm in length and 0.33 mm in breadth. The full-grown grub is about 2.85 mm in length and 0.98 mm in breadth. The grub period may be as short as eight days. When full-grown, the grub makes a rough chamber inside the stem and pupates therein. The pupa measures about 2.07 mm in length and 1.08 mm in its maximum breadth. The pupal period may be as short as four days after which the adult weevil emerges either through a passage made earlier by the grub during its normal feeding activity or by making a fresh hole for its own emergence. The adult is a tiny weevil about 1.8 mm in length and 0.8 mm in breadth and with a very conspicuous snout. It is dark brown or dull black in colour, clothed with small whitish setae. The whole life-cycle can be completed in about 15 days but the maximum longevity of the adult has been reported to be as much as 209 days. Thus, there are a large number of overlapping generations during a year but winter is generally passed in the adult stage, the weevils concealing themselves in various bushes, shrubs and hedges in the highlands near the villages and as soon as the new crop comes up, they emerge out and attack the nearest crop. Therefore, the fields far away from the winter shelters are less attacked. There are a number of alternate host-plants but the *capsularis* just seems to be the most favoured host-plant. The damage in the apical portion is comparatively less in late-sown crops mainly because from July onwards the weevil prefers to oviposit in the basal region. Nitrogenous manures increase infestation but potash and phosphatic fertilizers decrease the same.

There are a few larval parasites which parasitize up to 50 per cent of the pest population.

As regards control measures, mechanical methods like destruction of immature stages by removing and destroying infested plants which also constitute a part of the normal thinning process, collecting and burning of stubbles, quick steeping of harvested jute which should be stacked only for four days during which majority of parasites emerge, etc. are quite effective. However, in the case of severe infestation a number of powerful persistent contact insecti-

cides are now available. They can be profitably made use of for killing the adults.

SPODOPTERA

(*Plate XXXII*)

Spodoptra exigua Hiibues, previously known as *Laphygma exigua* Guenee, is a polyphagous noctuid pest. It has been referred to as the indigo caterpillar because in earlier days when the indigo industry was flourishing, this pest used to be quite injurious to young indigo crop. Its generic name has undergone a change from *Caradrina* to *Laphygma* and now to *Spodoptera*. The area of its world distribution includes Europe, South Africa, America and the oriental region. In India too, it is quite widespread. The list of its food-plants includes jute, indigo, lucerne, lentil, cabbage, maize, cotton, etc. It is reported to have a particular liking for lucerne leaves so much so that lucerne has been suggested as a trap-crop.

The adult stage is a typical small noctuid moth with dark-spotted forewings and white hindwings. The moths hide in shelter by day and come out and fly about for mating and egg laying at dusk. They lay eggs on leaves in clusters of up to 200 eggs each. Each egg is spherical like a poppy-seed in shape and size but with radiating lines. These egg-clusters are often covered with buff-coloured hair which are also present in-between the eggs. The egg-period can be between 24 to 36 hours. The caterpillars, on hatching, gather on the leaf surface, the epidermis of which they eat. At this young stage, they are also in the habit of webbing together either several leaflets or the margin of the same large leaf. At times, these webs give a webby appearance to the crop. Within these webs the young larvae live gregariously only for two or three days and thereafter they separate and spread out. At this stage, they acquire a new habit of hiding under other kinds of shelter particularly when they are not feeding. Their feeding activity is generally confined to a few morning hours, say 9 to 11 a.m. and then again after 4 p.m. or so. They are very voracious and quite large patches of foliages are quickly stripped. The colour of the larva is very variable, depending on the crop on which it has been feeding. When full-grown and full

fed the caterpillar seeks shelter usually on the soil surface at the base of the plant, under stones or among leaves and such other debris. Also when necessary, a small amount of webbing is produced as a covering and a very rough cocoon is formed with bits of leaf and other material. Inside this cocoon the larva pupates and the chrysalis is of the usual noctuid type with a double spine at the tip of the abdomen. The pupal period may be as short as five days and the whole life-cycle can be completed in less than three weeks. But the life-cycle can be very much lengthened, depending upon the environmental temperature and humidity.

The pupal period responds very much to the environmental conditions.

When temperature falls during November, the full-grown caterpillars pupate in sheltered places and then they hibernate during the whole of winter. As the air warms up in February, some moths emerge but soon thereafter the emergence ceases because the air becomes very dry. Further emergence takes place only when the air again becomes moist. The response to the moisture content of the air is so much that humid easterlies induce emergence but dry westerlies delay or postpone the emergence. However, once the moth emergence takes place and eggs are laid, these eggs are quite resistant even to hot dry air with 41°C temperature and 30 per cent R.H. Also, caterpillars can be reared even under very dry and hot weather, provided moist food is available. In other words, partly structurally and partly behaviouristically, the pest is well-adapted to its life under fairly variable conditions of environment.

There are a number of enemies of this pest, particularly in the larval stage. These enemies consist of not only insect parasites and predators but also vertebrates. In fact, it had been suggested at some stage that lucerne should be grown mainly to raise a good population of *Spodoptera* which would nurture parasitic fauna, and this parasitic fauna in turn will save other crops that follow the hot and dry periods of summer.

From the foregoing account it will be seen that the only really feasible non-chemical control is the collection of egg-masses although in the past even collection of larvae has been tried and there is a report of successful collection of about 20 kg of larvae numbering 250,000. For chemical control, a strong insecticide with

both contact and stomach poison effect and preferably persistent in nature should be chosen.

Suggestions for Integrated Control Schedule for Jute Crop

The points which should be kept in view in formulating integrated control schedules against the pests of jute crop are:

(1) To grow the *capsularis* species in areas where the stem-girdler creates a bottleneck in jute cultivation.

(2) To try to nip in the bud pests like the stem-weevil and *Spodoptera* by mechanical campaigns of removing and destroying plants infested by the stem-weevils and collection of egg-masses of pests like *Spodoptera*.

(3) Chemical control by means of highly persistent insecticides with contact and stomach poison effect against the pests which do not succumb to the above methods.

CHAPTER X

PESTS OF FRUITS AND FRUIT TREES

IT WILL be recalled that in the case of oilseed crops, it was stated that the group was quite a heterogeneous assemblage of economic plants which belong to a number of quite unrelated families and which followed a course of what may be called a convergent evolution leading to their specialization in oil-producing capacity. A parallel statement can be made with much stronger justification in the case of fruit trees. In fact, the group of fruit trees is a much bigger and much more heterogeneous assemblage. Hence, the pests of these are equally heterogeneous. All the same, it is advisable to treat them in one chapter because it will be of special interest to a definite group of farmers who can be called orchardists. Also, the most important common characteristic of the fruit trees is that most of them are perennial trees as distinct from seasonal crops. This fact is of very great importance so far as the overall strategy of pest control is concerned.

There are many species of fruit trees. Some of them like apple, pear, plum, walnut, apricot, etc. are called temperate fruits particularly because they can withstand much lower temperatures in their dormant state, while others like citrus, mango, guava, pomegranate, cashew, etc. are called tropical or sub-tropical.

There are several hundred pest species of fruit trees and it should require a separate volume for doing any reasonable justice to this group of pests. However, it is hoped that the ten pests described in some detail in the following pages will give a fair idea of the nature of the pest problems involved in orchard maintenance.

Fruit-flies which constitute a very serious problem for orchardists have already been discussed along with pests of vegetables. The pest problems of dried fruits are more or less similar to those of storage pests to be discussed later.

SANJOSE SCALE

This pest (*Quadraspidiotus perniciosus* Comstock) owes its com-

mon name to the city of Sanjose in California, U.S.A.; it first attracted serious attention in 1873. This important member of the scale insect family Coccidae is believed to be a native of China but today it has spread to practically all parts of the world where deciduous fruits are grown. It is believed to have been got introduced into India first in Jammu and Kashmir State where some flowering plants were imported for garden decoration and the same happened to be infested with this insect. Its seriousness, however, was first realized only in 1922 and a systematic survey carried out during the late thirties and early forties showed that it had already spread to all the fruit-growing areas not only in north India but also in south India.

The Sanjose scale has a very wide range of host plants the number of which runs up to 200 belonging to nearly 28 plant families; all the same, it appears to have a special preference for the members of the plant family Rosaceae. The seriousness of this species can be gauged from the record that in 1922 more than 1,000 acres of mature apple trees were killed in southern Illinois due to infestation by this pest.

Each insect is pretty tiny with still tinier sucking mouth-parts with which it sucks the plant sap, but its numerical strength often reaches such proportions that even big trees succumb to its damage. Lightly-infested trees show greyish specks on the surface and at times there is a reddened area around each speck particularly on young shoots; but in cases of heavy infestation, the entire surface of the bark is covered with a grey layer of overlapping scales and appears as if the branches have been sprinkled with wood ash when wet. With such a constant drain on the plant-sap, it is but natural that the whole plant gets desapped and death of the tissues starts from the periphery. At times, even the fruits get infested and look specky and thus adversely suffer in their market value.

If a twig lightly infested with the Sanjose scale is examined under a magnifying lens particularly early in spring it will be found to be studded with two kinds of specks or scales as they are called. The one which is a female scale is almost round in shape with a raised nipple like projection in the center and the other type which is the male scale is rather elliptical with a nipple-like projection situated in the wider region of the scale. The former remains scale-like thro-

ughout but from the latter comes out a two-winged male insect. Thus, there is a very distinct sexual dimorphism in this species.

The Sanjose scale overwinters in partly-developed nymphal stages which remain tightly stuck to the bark under the two types of scales described above. During spring, these nymphs begin to develop quickly depending on the temperature and soon winged male adults emerge and mate with females which also by this time have moulted a number of times and have become mature without shifting from the points where they had remained from the very beginning of their nymphal life. These females are ovo-viviparous, i.e, their eggs develop within the body of the female and the young nymphs emerge out from within the female scale. Each female can continue to reproduce in this way for several weeks, depending on the temperature. These young ones are very small and they crawl about over the surface of the plant-twigs for a short time till they find a suitable place where they insert their sucking mouth-parts and begin to suck the plant sap. Nymphs at this stage are also called crawlers. From now onwards these creatures become stationary—the female for the whole life and the male till it transforms itself into a winged adult. At the very first moult which occurs after about 10 to 12 days, the nymphs lose their legs and antennae and thus lose the power of locomotion. During spring and summer, the whole nymphal period can be completed in about a month or so and there can be a number of generations from early spring to late fall when dormancy starts. The mortality of the overwintering population is often quite appreciable. For example in Kashmir, it is reported that although scales enter into hibernation in various stages of growth, only those survive the winter which have reached the size of 1/8 cm and have secreted grey scales over themselves. All other stages invariably perish during the winter.

It should be obvious from the above that the intrinsic power of locomotion and speading is very limited, in this pest; all the same, it has spread quickly all over the world. Trans-continental spread takes place through human agency carrying infested stock from place to place. Local spread is brought about accidentally, by the crawler, on the bodies of birds and other larger insects or also by air currents with which the crawlers can be blown about.

Being stationary for the major part of its life, this pest has a

very large number of natural enemies in the form of insect parasites, parasitic fungi, insect predators, bird-predators, etc. All these, together, exert a considerable check on the population build-up of the pest. All the same, unaided by human agency, these natural enemies are not able to keep the pest below economic level particularly in the regions of temperate fruits.

As regards chemical control, the only recommendation in earlier times used to be to spray the infested trees during the dormant stage in winter with various formulations of mineral oils, which, if used during the active season, will prove highly phytotoxic. Some insecticides like DNOC were also incorporated into these winter washes as they are called. During the last two decades, however, a number of highly toxic chemicals have come into the market which can be used during the full-growing season without any fear of phytotoxicity and which are quite effective against the Sanjose scale. These sprays are now so popular that it is at times difficult to check the growers from treating their orchards. The only serious problem now is that this pest attacks such a large variety of fruit and forest trees, that it is not possible to carry out chemical control on all the alternate hosts. The result is that chemical control proves to be a very temporary palliative as the infestation on the un-economic trees surrounding the fruit orchards is always very heavy and therefore the good effect of the chemical control is very soon lost. The result is that orchards have to be treated again and again during the same season. In order to overcome this difficulty, it is highly advisable to integrate chemical and biological control for keeping this pest economically under control. It is advisable to treat the orchards of valuable fruits like apple, etc. by means of suitable insecticides and to carry out intensive biological control of the pest in the surounding area of such trees as cannot be economically treated with insecticides. In areas like Kashmir, it is highly feasible that a parasite like *Prospeltella* sp. be reared in very large numbers in specially heated rooms during the whole of winter season. The parasite population can be rapidly built ten to twenty-fold during each generation of about four weeks and then the areas covered with the comparatively small overwintering population of Sanjose scale on uneconomic plants can be flooded with these parasites which can keep down the infestation inocculum in these areas around the

fruit orchards. In this way, the infestation from outside the orchards can be very effectively checked, resulting in a reduced number of sprays in the orchard itself. This is a very fertile field for an effective and fruitful integration of chemical and biological control both of which can be applied simultaneously in time but in distinctly separate areas.

WOOLLY APHID

Eriosoma lanigerum (Hausmann)

The epithet woolly has its justification in a kind of white powdery secretion which is produced by numerous glands on the body of the aphid and which gives a general appearance of cotton-wool covering often large colonies of this aphid pest, the adult body colour of which is actually purplish.

This is a very serious pest in practically all the temperate regions and pockets of the world where temperate fruits are grown. Although it attacks a number of fruit trees, its seriousness on different species differs from region to region. In India, it has been a very harmful pest of apples ever since it was introduced into this country via Britain sometime in the beginning of the present century; it is considered to be a native of America.

The nature of damage caused by this aphid is essentially similar to what has already been described in the case of the mustard aphid but the distinctive feature of the damage by the woolly aphid is that it takes place in a very large measure even in the root region where it is very difficult to control. The infestation in the aerial portions of the plant is spread to all parts like the trunk, the stem, the branches, tips of twigs, fruit stocks, leaf petioles, etc. Their infestation is often associated with the formation of various kinds of deformities, large knots, etc. both on underground and above-ground portions but this association can also be due to the fact that at times these aphid colonies cluster in wounds resulting from other causes. All other symptoms due to desapping of the plant, like a sickly appearance, a stunted size, loss of vigour, etc. are also produced and the fruiting capacity of the trees is very much reduced. The infestation in the underground portion at times results in such

a severe disintegration of the roots that the trees get uprooted by wind.

The life-history of this pest is quite interesting and adaptable varying in detail from place to place obviously depending on the climate of the place. The overall simplified picture of the life history is somewhat as follows : The pest overwinters generally in two stages, i.e. either as eggs or as immature nymphs on the underground portions of the host-plant. The eggs hatch and the nymphs mature during spring when active development and breeding start, depending on the temperature. The form of reproduction in this season is by parthenogenesis and vivipary, i.e. the females reproduce without mating with males and they give birth to young ones instead of laying eggs. The nymphs soon settle down to feed on the plant-sap and within 24 hours thereafter begin to secrete the woolly filaments of wax over their body. They undergo four moults before they become adults and this process may be so quick as to take only about 10 days, although this period may get lengthened to near-about 100 days when it is very cold. During the whole of summer and the monsoon, the reproduction is very rapid and both winged and wingless forms are found. There is considerable dispersal of the pest at this time both by the flying of winged forms and by passive dispersal of wingless forms either due to wind or on bodies of larger animals. There is also considerable migration from the aerial region to the root region and vice versa. During fall and particularly when winter approaches, the sexual forms appear, mate and lay eggs. Also at this time, there is migration from the aerial region to the root region for hibernation in nymphal stages.

The variations recorded from place to place which are obviously due to variations in the climate are with respect to migration from the aerial region to the root region and *vice versa*, production of sexuals and oviparous forms, niches in which overwintering takes place, etc. These variations are more or less on expected lines. For example, where one-sided partial migration between aerial and underground regions takes place, it is from root to shoot in spring and *vice versa* in fall or winter. This is quite easy to understand and quite purposive in nature. In other places like the Kurrum valley, hibernation takes place in viviparous female forms which remain lurking under loose barks of trees and other crevices and which come

out of these shelters in spring and go back to the same if a cold spell comes up again. Where winged forms are not found during summer, they are produced during the fall, obviously for securing wider dispersal and ensuring greater chances of survival during winter. Thus on the whole, it appears that quite interesting and fruitful results are expected if the bionomics and ecology of the woolly aphid are studied from this angle.

Like other aphids, *Eriosoma lanigerum* has also a number of natural enemies in the form of parasites and predators. What is special about this pest is that its economic importance in India is reported to have been brought down from that of a very serious pest to that of an insect of very little significance and this tremendous change is believed to be the result of introducing an exotic parasite *Aphelinns mali* Hald from the original home of the pest. Similar successes have been reported from several other countries as well where the pest had got introduced inadvertently and where the parasite was introduced as a planned attempt for biological control.

As regards chemical control, the insecticides recommended in earlier days used to be rosin soap and nicotine preparations for killing the pest on the shoot and chemicals like paradichlorobenzene for fumigating the underground infestation. Now, however, there are a number of very powerful organophosphorus compounds, for aerial spray and also a number of systemic insecticides against root infestation. However, the practical details and precautions for utilising these modern chemicals need to be carefully investigated in different regions and different species of fruit trees.

FRUIT-SUCKING MOTHS*

[(Clerck) and *O. materna* (Linnaeus)]

These are quite large noctuid moths belonging to about twenty different species, the wing-span of some of them being about 1 cm or more. Generally, moths and butterflies damage the plant or plant products only during their larval stage but fruit-sucking moths as their common name indicates damage fruits in their adult moth stage. These moths damage the outer skin and then suck the juice of fruits like the orange, guava, peach, pear, etc. This damage results

*Most common and destructive are *Otheris fullonia*

not only in fruitfall but also exposes the fruits to a number of other insects, fungi and bacteria due to which the fruits rot or at least severely suffer in quality because of the scar left on the fruit even if the wound caused gets healed up.

Another very important peculiarity of practically all fruit-sucking moths is that their larvae feed on entirely different plants most of which grow wild and even quite far away from the fruit orchards. The result is that the breeding of these insects takes place often outside the orchard and as the larval food is often of no economic importance, ordinarily nobody even takes notice of its breeding. This phenomenon makes the control of these pests specially difficult. Just as for the control of flies and mosquitoes the attack has to be concentrated on their breeding places, these pests should also be rationally killed in their larval stages. But there are two main difficulties: the first that it is difficult to spend as much on these pests as one can in the case of flies and mosquitoes which cause serious problems of human health and when it is so difficult to control those vectors of human diseases how much more difficult it will be to control these fruit pests ; the second is that the food plants of larval stages of fruit-sucking moths are much more widely and sparsely scattered. However, there is one point which should make the control of fruit-sucking moths in their larval stages slightly more feasible than mosquitoes and flies and that is that in the present case the larval food-plants have to be eradicated and this can possibly be tried with success if a concentrated campaign is organized on a really large scale. The group of pests somewhat parallel to fruit-sucking moths is that of chafer beetles the larval stages of which are serious pests as white grubs and adults as serious pests on the foliage of fruit-trees. However, as white grubs and chafer beetles are both serious pests of economic crops, one is likely to be more inclined to spend on these pests.

The control which is considered to be more feasible is the baiting of the fruit-sucking moths themselves. The attractants used for baiting purposes generally consist of fruit-juice mixed with crude sugar and water to which a suitable poison is added. This bait-mixture can be kept in wide-mouthed vessels so that the moths may be attracted to feed on this poisoned syrup and die. The success so far is only partial. The only rational approach

is to take a realistic view and organize large-scale campaigns financed by orchardists as a co-operative venture.

Other aspects of the biology and life-history of these pests are fairly similar to those of any other noctuid pests, several of which have already been described in previous pages. The moths lay eggs on the larval food-plants and the resulting caterpillars spend their life up to the pupal stage on or near their food-plants and the adults after emergence fly often quite long distances to feed on fruits in orchards of the area.

CITRUS LEAF-MINER

(*Phyllocnistis citrella* Stainton)

(Plate XXXIII)

The leaves of various species of fruit-trees belonging to the citrus family often show white glistening irregularly-zigzag galleries within the leaf lamina. The tunnelling is done by the larvae of a moth scientifically named *Phyllocnistis citrella* Stainton and commonly called citrus leaf-miner. Due to the extensive mining by the pest, the leaf suffers badly, gets deformed and irregularly curled up in shape, unhealthy in look and defective in its function and finally it dries and falls off. At times, even the young shoot is attacked. Consequently, the whole plant suffers and also becomes prone to diseases like citrus canker. As expected, succulent leaves with thin epidermis are more suitable for the penetrating and mining activities of the tiny larvae. Hence, the attack is comparatively much greater in leaves of fresh growth, young seedlings and varieties with characteristics of having soft succulent leaves.

The adult stage is a tiny greyish moth with a wing-span of 8 to 10 mm. The forewings are white with two narrow grey stripes and the hind-wings have pale grey fringes. These moths lay minute flat eggs singly on the underside of leaves and these eggs may hatch out in as short a period as two days. The larva as it hatches out is legless but it soon enters the leaf tissue and begins to feed inside it and mine the leaf lamina. The larval period may be as short as five days after which the larva comes out and pupates

near the margin of the leaf which folds up to provide a sort of cover over the pupa. The pupal period can come to an end in about five days after which the moth comes out and starts a new generation. Thus, one generation can be completed within about two weeks, although it can also sometimes take about two months, depending on the environment when all the developmental periods given above get lengthened. This cycle of generations continues practically the whole year except that the development gets prolonged in the colder months and even moth activity may cease if it is very cold, say, during December and January.

The control of this pest is not as easy as that of the external pests but also not as difficult as that of many internal feeders. This is so because the thin covering over the larval galleries is not very impervious. Hence, emulsions of insecticides which are not phytotoxic can be more useful. Sprays containing nicotine, parathion, etc. have been reported to be useful but emulsified formulations of somewhat more persistentin secticides are likely to provide a more prolonged protection and preventive cover.

LEMON BUTTTERFLY

(*Papilio demoleus* Linnaeus)

(*Plate XXXIV*)

This is a very common and attractive butterfly with which everybody is bound to be familiar although few suspect it to be harmful in any way. It will take quite a good space to commit to writing the beauty and aesthetic characteristics of this insect but a coloured illustration (plate xxxiv) is quite enough immediately to pinpoint what is being discussed in these few paragraphs.

So much is common between moths, a number of which have already been described, and butterflies, to which group this insect belongs, that it is only necessary to point out a few differences. The most prominent difference between moths and butterflies lies in the pattern of the resting position of the wings, those of the moths being flexed laterally downwards in slanting roof-like disposition on either side of the body-length, while those of the butterflies are held juxtaposed over the back and

perpendicular to the surface on which the insect rests. The other important difference which can be made out after a little close examination between the two groups of the same order is that the feelers or antennae as they are called, are club-shaped i. e. thick at the end in butterflies, while they are either filiform or pectinate in moths. The third and economic difference is that while a very large number of moths are serious pests of crops and fruit-trees, the number of serious pests is comparatively small in butterflies.

Thus, the lemon butterfly is one of the fewer species of this group which is quite harmful in its larval stage and an object of beauty and aesthetics in its adult stage which lends charm to the environment in which it flits about.

This species is widely distributed in the Indian subcontinent and it is found right from Arabia in the west to Taiwan in the east. The food-plants of its larval stage include various species of citrus and also a number of other plant genera.

The female butterfly lays yellowish-white eggs on young leaves and tender shoots. The eggs are scattered singly instead of being laid in batches. These eggs hatch out within a couple of days into dark-brown caterpillars which eat the leaves of the citrus trees and which after a few days develop such irregular whitish markings on the body surface that they look as if they are not caterpillars but some irregular masses of bird excreta. Obviously, this is a protective adaptation to escape the notice of their predatory enemies like birds who would not like to pick up their own droppings. It is, however, interesting that later on when almost full-grown, these caterpillars put on a green colour and move away in various directions and pupate while hanging from the twigs. One complete generation may take as little time as two-and-a-half weeks and as much as four-and-a-half months. Generally, there are several generations during a year and the winter is passed in the pupal stage.

As regards control, this pest can be picked up mechanically in larval and pupal stages if its population is low or when the attack has just started. In cases of severe infestation, there is no alternative to a chemical treatment with some strongly persistent insecticide having both contact and stomach poison effects.

ANAR BUTTERFLY

(*Virachola isocrates* Fabricius)

(*Plate XXXV*)

This is another butterfly pest of several fruits and particularly pomegranate which is distributed throughout India. The list of food-plants of this pest also includes guava, apple, orange etc. The larva bores into the fruit and feeds on its contents. It actually creates a lot of mess and offensive smelling matter oozes out from the entrance hole ; obviously, the wound caused by this pest gets infected with a number of bacteria, fungi etc.

The female butterfly lays eggs singly on various parts of the shoots but the young caterpillar which hatches out within a week or ten days instead of feeding on the leaves bores into the fruit. The larval period may last from two weeks to one-and-a-half months. The pupation takes place either on the stem or even in the fallen fruit and the pupal period varies from a week or so to more than a month. The breeding of the pest continues thoughout the year with varying speeds depending on the weather,

As the larva bores directly into the fruits, there is no satisfactory control measure for this pest although the infestation sometimes is so severe that up to 90 per cent of the fruits, may become wormy. It is one of those pests on which eonomic entomologists should undertake detailed investigations. A promising line should be to identify attractants for the adults and ultimately develop poison baits so that the adults can be killed before mating and egg-laying. The recommendation for the present should be to launch a concerted campaign to collect and destroy all infested fruits from large compact areas in the beginning of the fruiting season, This can alone save a commercial orchard. For small trees in a compound, one can easily resort to bagging of individual fruits.

MANGO HOPPERS

These are the insects which cause a humming noise and almost dart into your face once you happen to walk below a mango tree

whose branches are not much higher than your height. This is too spectacular a phenomenon to be ignored particularly during the July-August period. These are the most serious pests of the mango tree. These pests belong to the family Jassidae ; hence their general characteristics are like those of the cotton jassids already described. The point which appears to be of special interest is that although there are three fairly important species *Amritodus atkinsoni* (Lethierry), *Idioscopus clypealis* (Lethierry) and *I. niveosparsus*, these are still reported to be, unlike the mango mealybug, monophagous, i. e. feeding and breeding only on mango. Like other jassids, they suck the plant-sap and due to this drain caused by a very large number of rather small individuals, the flower-buds, flowers etc., first become flaccid and then wither and die. This affects the fruit-set very adversely and the young fruits fall off. Also like other jassids, they produce the sticky honeydew which encourages the development of sooty mould and which in turn not only gives a sickly look to the plant but also hinders the photosynthetic activities of the leaves which are covered with the sooty mould.

The size of the different species varies from about 4 mm to about 6 mm and there is considerable over-lapping in this character. Also, both the structure and the habits of the three species differ. only in slight and rather unimportant details.

After spending winter in the adult stage, the mother-hopper lays eggs within the tissues of tender shoots, flower-buds, tender leaves, etc. These eggs hatch within a period of one week or ten days. The nymphs soon after hatching begin to suck the plant-sap. The nymphal period is completed within two to four weeks only. Thus, there can be several generations during the year but generally there are two peak periods of activity—the first during February to April and the second during June to August. The nymphs perfer damp and shady places particularly during the midday.

As regards control, use of any strong contact poison can be recommended but in choosing a suitable insecticide it should be kept in view that sometimes the use of an insecticide may lead to increased trouble due to mite pests. Hence, a little experience of the local situation is necessary. Also, systemic insecticides can be quite successful in controlling the pest but they cannot be recommended

unless the questions of toxic residues of systemic insecticides inside the fruits of the treated trees is satisfactorily investigated and solved.

MANGO MEALY-BUG

(*Drosicha mangiferae* Green)

Plate XXXVI

Both orchardists and those who have a number of mango and other trees in their compounds are generally familiar with the large fleshy flat-bodied creaures with a length of up to about a centimetre and half and a breadth of a little less than a centimetre, covered with ashy-white mealy powder and crawling up or down tree-trunks or on the ground round the tree-base or even invading the houses if the mango trees are near about. These are the mango mealy-bugs and because of their large size, they are also referred to as the giant mealy-bugs ; they are too prominent not to attract attention even when they are small in number and they create a rather alarming nuisance when they are in large numbers, necessitating an s.o.s. to those who are likely to know about such matters. These are insects belonging to the bug group. Thus, their common name is self-explanatory. Like most bugs they suck the plant-sap and although their name seems to suggeest that they are specific pests of mango only their list of foodplants includes at least 62 species of trees, shrubs and herbs, like mango, guava, peaches, plump, rose, castor, etc. Their sucking activity, when they are in large number, devitalizes the plant and they produce honeydew which encourages growth of a sooty mould, giving a very unhealthy look to the plant as a whole. At times, they are found clustering in masses on young shoots. like fungus outgrowths.

The scientific name of the most common species of this pest is *Drosicha mangiferae* and it has been reported from many places in India and China.

There is a well-established sexual dimorphism in the adult stage which is generally found during the midsummer period, i.e. from April to June. The description given above applies to adult females which are wingless and large-bodied. The male, on the other hand,

is a winged creature with only one pair of wings and a very delicate reddish body which flies actively and fertilizes the females. The male adults have also much shorter longevity than the female adults which live for about a month. The adult gravid females after fertilization crawl down along the tree-trunk to the ground where they lay eggs at depths of about 5 to 15 cm and in clusters of 300 to 400 eggs each. The oviposition is generally confined to an area near and around the base of the tree. These activities of migration from the tree downwards to the ground and oviposition in the soil are generally confined to the months of April, May and June. The males die soon after mating and the females soon after oviposition.

The eggs laid in the soil take quite a few months before they hatch and their hatching has been reported to be quite appreciably influenced by the temperature and moisture conditions of the soil. The result is that hatching can be as early as November of the same year or as late as March of the succeeding year. Late monsoons and winter rains have been reported to delay hatching.

The young nymphs soon after hatching crawl about in search of some suitable food-plant on which, if found, they spend some time. Thereafter, they begin their ascent along the tree-trunks and this upward migration lasts for several weeks. On reaching the fresh growths, the nymphs congregate there and begin to suck the plant-sap. They moult thrice during their nymphal period which lasts about three months or more, depending on the environmental temperature. Thereafter, the nymphs developing into males undergo some sort of pupation and transform themselves into winged adults and the female-producing nymphs do not undergo any appreciable change except in size. Thus, there is only one generation during the year. Unlike many other coccids, the nymphs of this pest do not remain stationary although they are sluggish.

From the foregoing account it will be seen that the rationale of the control of this pest is somewhat on the following lines :

(*a*) Raking of the soil around the base of the tree which has been infested, so that the egg-masses get exposed to the sun and heat and get killed. Also, the application of a soil insecticide in the same area when hatching begins or is expected, so that the just-hatched nymphs may be poisoned.

(*b*) Application of a sticky band round the tree-trunk so as to check the nymphs from crawling up the trees. Many kinds of sticky bands have been recommended. Incorporation of insecticide in the sticky band is likely to increase the effectiveness of this band. Even making a fairly wide insecticidal barrier round the trunk can lead to effective poisoning of the nymphs. In recent years it has been found that banding the tree trunks with 300 mm wide alkathene sheet of 400 gauge prevents the ascent of mealy-bugs.

(*c*) Strong organo-phosphorus insecticidal sprays which can penetrate the waxy covering over the nymphal body can control the pest but such applications are likely to be more effective if carried out when the nymphs are young, and the concentration of the sprays has to be considerably increased if they are to be applied when the pest is in the advanced stages of its development.

BARK-EATING CATERPILLAR

(*Indarbela* spp.)

(*Plate XXXVII*)

Orchardists often feel annoyed, discouraged and disappointed at the sight in their gardens of a dirty, elongated, zigzag, ribbon-like messy web consisting of bits of bark pieces, excreta etc., an inch or more in width and even up to two feet in length, covering the trunks and branches of trees of various species. At times, several such webs are found on each tree and their very presence gives an unhealthy look to it. While trying to clear up this mess, one finds that these elongated webs cover a gallery of an inch or so in width leading at times to a hole generally in the angle of the thick branches and within this gallery or the hole a caterpillar is found generally unless one is dealing with an old abandoned gallery. This is commonly know as the bark-eating caterpillar and it is the larva of a large-sized moth which specialists will identify as a species of *Indarbela* (*I. tetraonis* Moore, *I. quadrinotata* Walker). The caterpillar is very harmful to the tree on which it is found because it feeds on the bark and in this process it seriously injures the plant tissues through which nutritive plant-sap is transported within the plant's

system; the result is that the tree-growth and fruit-bearing capacity are adversely affected. At times, the infested branches can dry up and in cases of severe infestation the whole tree may die. It is a peculiarity of this pest that it prefers older trees to younger ones. The infestation in some areas of the country has been reported to be more than 40 per cent.

The life-history as worked out in a central region of India is somewhat as follows : The adult is a large-sized moth with a wing-span of about 4 cm in the female and about 3 cm in the male, light grey to light brick-red in colour and with dark brown patches or dots.

The female lays a very large number of eggs but in small groups of 15 to 20 eggs each. The egg-laying takes place in May and June and the incubation period is about 10 days. The caterpillar soon after hatching begins to feed on the bark and prepares the web under which it lives. The larval period is quite long and the caterpillar continues its destructive activity from May-June up to April the following year. During this long period, it grows slowly being about 1.5 cm in September to about 4 cm by December when it is practically full-grown. The larval habit is quite important. It remains in hiding practically the whole day and comes out for feeding on fresh areas only during the night. From April onwards, the population starts. It takes place within the larval gallery and the pupal period is only three to four weeks. At the end of the pupal period, the pupa wriggles up to the opening of the gallery wherefrom the moth emerges, leaving the pupal skin protruding from the exit hole. The moth's life is quite short and it completes egg-laying within two or three days after which it dies.

The list of trees attacked by the bark eating caterpillar is quite large and include mango, guava, pomegranate, jamun, etc., which are commonly found in ordinary gardens.

The main feature which should be fully exploited for its control is that its presence can be easily spotted out even from a distance due to the prominent web it makes. Hence, the rational approach is to clean the web and fumigate the hole with an ordinary fumigant by putting in the hole a swab of cottonwool dipped in the liquid fumigant and inserting the same in the hole which should thereafter be plugged with mud. Another somewhat simpler

approach is to inject a strong persistent insecticidal liquid formulation into the web of the larva and also smear the same up to quite a distance outside the hole so that when the larva cames out in the night it may get poisoned. The insecticide should have both contact and stomach poison effects, and it should be as persistent and strong as possible.

MANGO STONE WEEVIL

(*Sternochetus mangiferae* Fabricius)

(*Plate XXXVIII*)

This is quite a peculiar pest which not only causes annoyance and aversion in mango-lovers but also mystifies them. In areas in which this pest is prevalent, it at times so happens that when one is about to eat a mango fruit which is apparently quite healthy, one is bewildered to find a fairly large-sized adult weevil emerging out of it and flying away. This creates aversion to eating the fruit because of the obviously unhygienic content of the apparently healthy fruit and bewilderment because unless one has learnt about its full life history one is not able to understand the apparent magic as to how the beetle got into the fruit when there was no external sign of any kind of entry-hole on the mango fruit.

The facts are as follows : The adult weevil is about 8 mm in length and about 4 mm in breadth, greyish brown in colour and with such a pattern as to make the weevil indistinct from the ground background of the bark of the mango tree. In the non-fruiting season, this beetle remains practically in hiding under the bark and in other niches. It can stay like this for months. Some say it feeds on the mango leaf in some seasons and others have observed that it can live without food and water for months. It feigns death when distrurbed. Its activities are generally nocturnal. However, when the fruiting season begins and the mango fruits are still quite tender, this beetle lays eggs on the surface of the mango fruit. The process of egg-laying is also quite peculiar. The mother-weevil surveys the surface of the fruit as if trying to spot out with the help of its snout and antennae a suitable place for egg-laying. Thereafter,

it carves out with its mouth-parts a boat-shaped depression which is so shallow that even liquid does not ooze out from it. Thereafter, the insect turns round and further assesses the suitability of the scooped out place and then lays there a single egg which it covers with a small quanity of transparent liquid secretion. It then turns round once more and makes, now with the help of its mouth, a crescent-shaped cut near the posterior end of the egg. This cut, unlike the shallow depression scooped out earlier, is so deep that there is quite a copious flow of liquid from it and liquid also covers the egg completely and dries up into a kind of resinous protective cover for the egg. This process of egg-laying is so precise and methodical that it takes on an average 15 minutes to lay one egg and one weevil lays up to about 15 eggs in a day and about 300 during a period of three months. There are several matings during the life-time of one weevil and egg-layings and matings at times alternate. Up to three dozen eggs can be found in a single fruit. These eggs hatch within a week or so and the just-hatched larva is exceptionally cylindrical in shape for a weevil larva. It immediately begins to burrow into the mesocarp flesh of tender fruit and soon reaches the region where the endocarp seed coat is still very soft. Once the larva crosses this barrier of the seed coat which is yet in the making, it reaches the region of the seed endosperm where it can spend the rest of its life in an environment of plenty and safety. If, however, the seed coat has hardened before the larva has bored it, then that larva has very little chance of survival. This fact seems to set a limit to the age of the fruit up to which successful infestation is possible. Inside the seed endosperm the larva feeds, grows, moults five times during a period of about five weeks, pupates for about seven days and finally transforms itself into the adult weevil. In the meantime, however, all the injury that was done to the mango skin, flesh and seed coat gets so nicely healed up that the mango fruit appears to be absolutely healthy with developed insects inside its stone and the number of these insects in a single stone may at times be as large as half a dozen. During this period if the infested fruit falls and its fleshy portion decays, then the adult cuts out an exit hole and emerges directly from the stone. If however, the fruit has not fallen, then the adult has to cut through the mango pulp to come out and

create the abhorring scene of the large insect emerging out of a nice healthy-looking mango fruit which the mango-lover is about to knife for eating.

As regards other interesting facts about the life-history of this pest, special mention may be made of the extraordinary longevity of the adult stage. It can live up to about 21 months. Even under unfavourable conditions, it can live for several months. It is also noteworthy that so far as is known, the pest is monophagous and attacks only mongo.

Another interesting feature of this pest is that it seems to be very sensitive both to temperate and to low humidity, so much so that in India it is confined mostly to humid areas in the southern and coastal regions. The same appears to be applicable to its world distribution because it inhabits all the mango regions bordering the Indian Ocean. It has not yet reached North, South and Central America. It is said to be a native of South-East Asia.

The nature of the damage is obvious from the foregoing account. As regards the extent of loss, sometimes even 100 per cent of the fruits are infested. All the same, under certain conditions the damage is mostly to the seed. For example, if the mango is consumed before the adult is ready to cut its way out, then practically no damage will be noticed. In such cases the main economic loss is left by those who deal in raising root stocks because the viability of the seed is bound to be very adversely affected. Also, a very great handicap is experienced in trying to develop the export market for mangoes. For example, the mainland of the U.S.A. does not allow mango imports from India mainly because of the apprehension that this pest may get indroduced into that country. Under these conditions, the control problem for this pest has two distinct facets : one is to reduce infestation below the economic level. For this purpose the best course is to kill the adults just before the fruiting season by thoroughly treating the bark where they hide. The second facet is to treat the infested mango with a view to killing the insect stage inside the stone by such means as will not harm the fruit in any away. It has been an unsolved problem in the world till very recently when we in India have been able to develop a hot water treatment which kills the insect stages inside the stone without causing any harm to the fruit itself.

Surprisingly, it has been discovered that this insect inside the seed stone gets killed by dipping the fruit in hot water at 50°±0.5°C for two hours, although the fruit fly larvae living in the pulp region, i. e. much near the surface, are not satisfactorily controlled. However, it is also possible to kill the fruit fly larvae present in the pulp by incorporating in the hot water a little ethylene dibromide (14.47 ppm). The bromide residues in the pulp, after 72 hours of such a treatment, have been found to be less than 1.5. ppm, which is much below the tolerance level of 10 ppm fixed by the Food and Drug Administration of the United States of America. It should therefore be possible now to explore the possibilities of exporting mangoes to countries where its import was not allowed.

CHAPTER XI

PESTS OF PLANTATION CROPS

PLANTATION crops provide ideal situations to intensive pest infestation and multiplication. Plantations are contiguous both in time and space. Crops like tea, coffee, coconut etc., are perennial. In time these plantations continue for 50 years and above and in space they are grown over extensive areas almost to the exclusion of other crops. From the ecological point of view, these factors are very conducive to the rapid population build-up of the pest species. From the viewpoint of economics, it has been well said, for example, that an investment in a coconut garden is one for a regular monthly income for over half a century. Once the bearing stage is reached, the tree continues to yield every month throughout the rest of its life for several decades. Hence, a mistake made in planning a plantation is also to be paid for during the same long period. This highlights the extreme necessity for a proper understanding of the ecological implications of establishing plantation crops.

PESTS OF TEA PLANTATIONS

Tea plantations receive such cultural treatment as induces the production of abundant succulent shoots for plucking. This factor is very conducive to the increase of the pest population. That is why the tea bushes in regular plantations are much more subject to pest attack than wild tea plants growing in a natural state in the jungles or even tea-seed trees in tea-seed gardens. On the other hand, it also seems to be equally true that the plantations actually suffer much less pest attack than what one would expect keeping the above mentioned conducive factors in view. Probably, one of the explanations for this latter phenomenon may be that tea bushes receive much more personal attention than many other crops. Tea is plucked at regular intervals. Hence, if some serious trouble is raising its head, it cannnot remain unnoticed for long. Also, pruning and defoliation are some of the cultural practices and these

operations are bound to be beneficial in keeping the pest under check. It is interesting to mention in this connection that one of the most serious pests of tea—the mosquito bug—seems to have developed the habit of laying eggs in the ends of shoots from which the leaf has been plucked so that safety is ensured for the eggs against any chance of being removed by pluckers. This is an example of the insects' reaction to such cultural practices as are likely to keep them under check. However, the tea plantations also provide ideal ecological niche for the existence of various types of predatory fauna which might be finding it worthwhile to prey on particularly large-sized pests.

There are as many as 147 insect pests of the crop described in *Pests of Tea in North-East India and their Control* by G. M. Das (1965) published by the Tea Research Association, Toklai Experimental Station. Only three out of these pests are being described in the following pages and their account is based mainly on the above publication.

BUNCH CATERPILLAR

Andraca bipunctata (Wlker)

(*Plate XXXIX*)

It is a widely spread pest of tea and potentially it is very dangerous. The caterpillar stage after the first two instars shows a rare peculiarity of huddling together during the day in large clusters on the branches of its food-plant. This peculiar habit is the basis of its common name, bunch caterpillar. It is found in India, Indonesia, Taiwan and Indo-China.

The adult stage is a moth with a wing-span ranging from 40 to 50 mm. It is brown in colour. Besides the wavy cross-lines, the forewings have two white spots near the outer margin. The hindwings are rather pale in the anterior region and brown in the posterior region. The antennae are bipectinate, there being small dark pectinations on white antennae. The mother-moth lays rather yellowish eggs in linear clusters on the underside of the leaf and a single moth can lay up to 500 eggs. The hatching of the eggs takes

place in about a week and a half and the just-hatched larvae are light-yellow in colour. They eat up their egg-shell before feeding on the leaf-tissue. There are five instars and these are passed in three to four weeks' time. The full-grown larvae are 50 to 65 mm in length and their body-surface has characteristic designs consisting of longitudinal and cross lines on an essentially dark-brown background. The gregarious tendency of the larvae persists up to pupation and the cocoons of one bunch are also found in a compact bunch although the caterpillars have to descend from the plant for pupation amongst dried leaves and other rubbish. The pupa is about 25 mm in size and reddish-brown in colour. The pupal period lasts for two to four weeks. There are generally four generations in a year in the north-eastern region of India.

The larval stage is subject to attack by a fly-parasite and a bacterial disease both of which are reported to be exercising a significant check. The gregarious nature of the caterpillars is quite conducive to such a biotic check. In fact, it should not be surprising if future studies in tea plantations reveal that these large bunches of caterpillars and cocoons are also lustily preyed upon by other bigger predators unless they are very offensive in palatability.

The weakest spot in the life-history of this pest against which control measures should be directed is the bunch-stage at which they can be easily detected, collected and destroyed. The detection is also rendered easy because of the prominent damage to the foliage caused by the pest. Of course, in a large acreage, the pest can also be attacked by means of a moderately persistent insecticide provided adequate precautions are taken against the residue problems involved.

PSYCHIDS

(Plate XL)

This is a group of insects known by different common names like faggotworms, bagworms, basketworms, etc. These insects have been chosen for description in these pages on the combined basis of their economic importance as pests of tea plantations and the curiosity they generally produce in a casual observer due to their

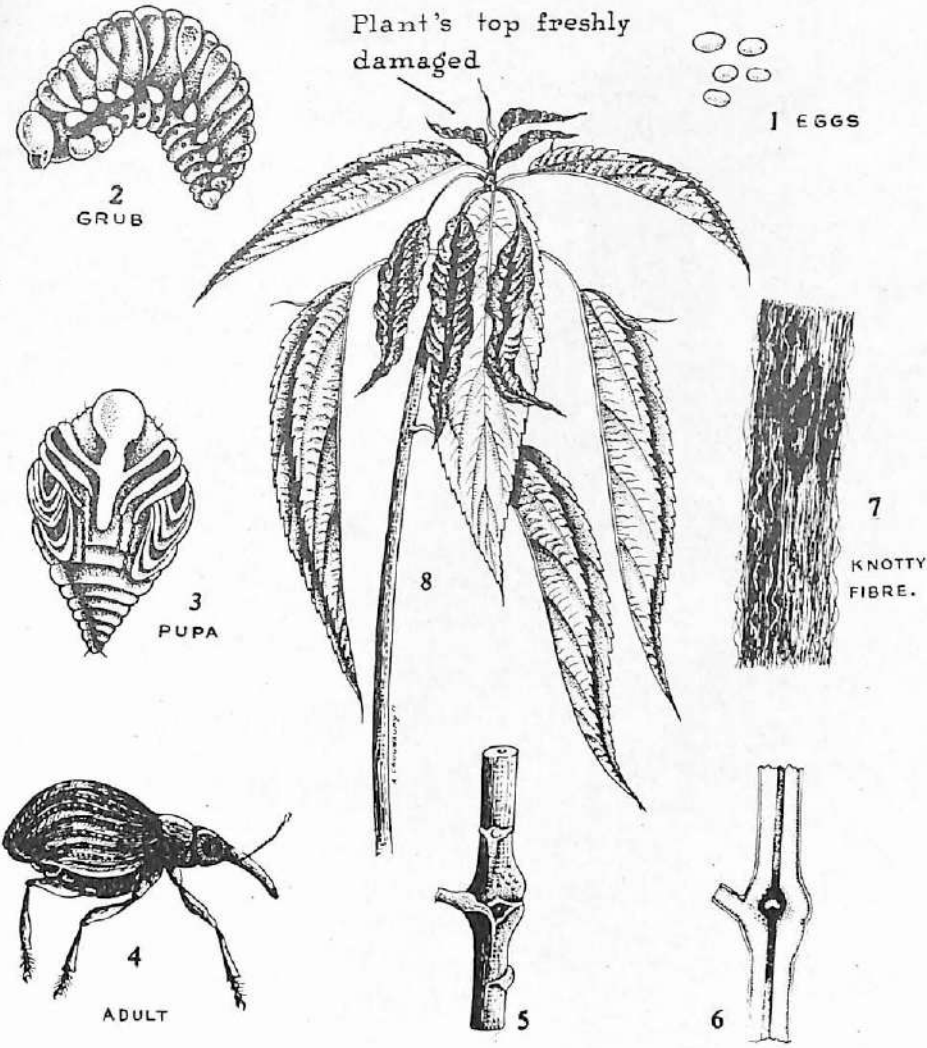


Plate XXXI—JUTE STEM-WEEVIL

1. Eggs 2. Grub 3. Pupa 4. Adult 5. Stem damaged
6. Split stem showing the site where the grub is found
7. Knotty fibre 8. Freshly damaged shoot.

(*Jute Bulletin*—June 1967. Jute Agricultural Research Institute, Barrackpore.)

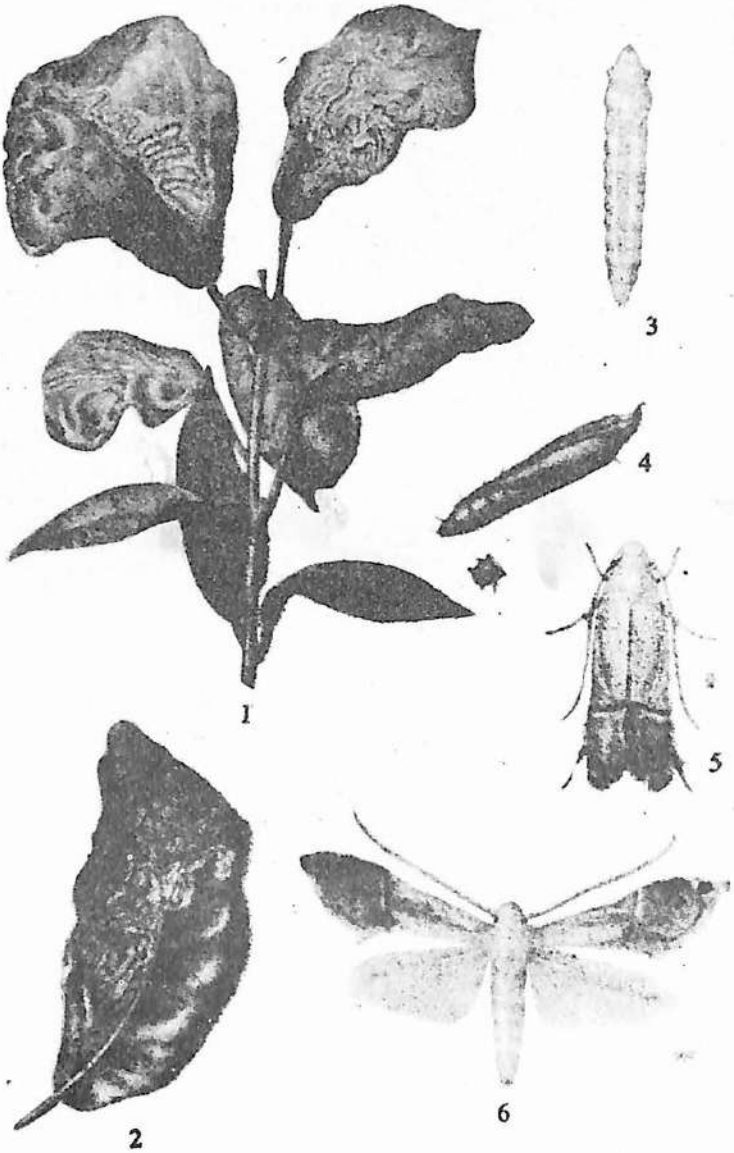


Plate XXXIII—CIRTUS LEAF-MINER

1. Citrus twig showing mined leaves 2. Mined citrus leaf 3. Larva 4. Pupa 5. Adult in resting posture 6. Adult (set).

(I.C.A.R., *Sci-Monog No. 16* Plate III)

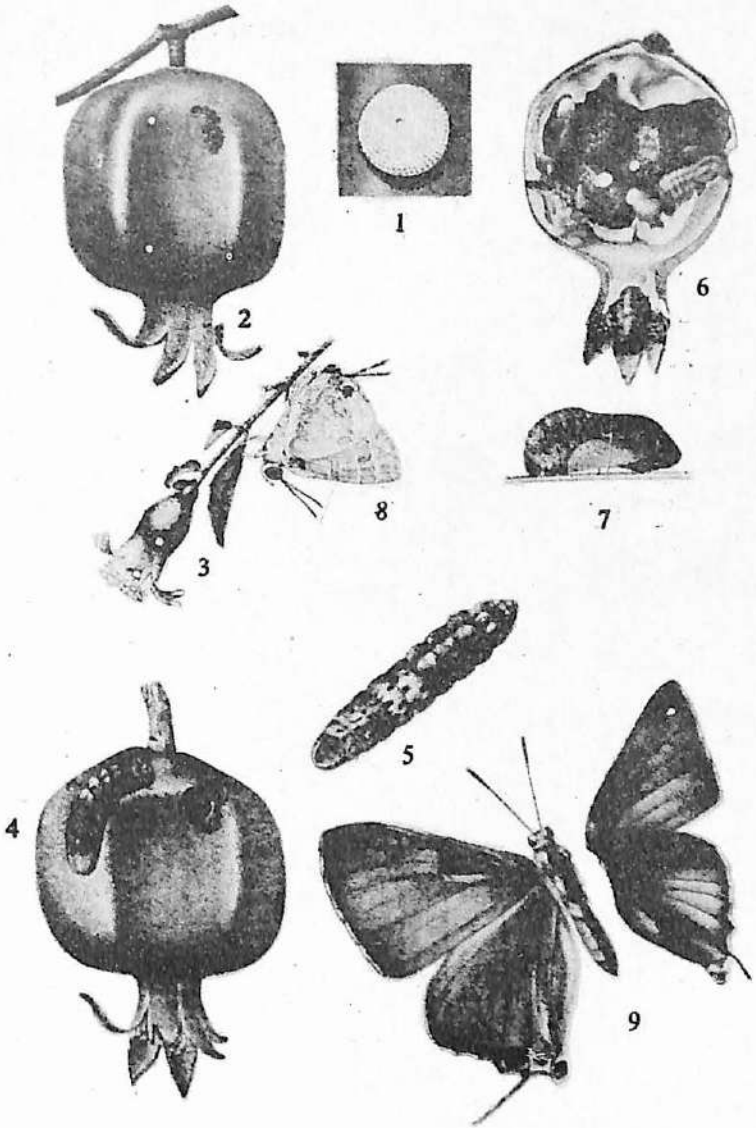


Plate XXXV—ANAR BUTTERFLY

1. Egg 2. Fruit showing two eggs on it and a hole through which the young caterpillar has gone in 3. Flower with two eggs on it 4. Damaged fruit with a nearly full-grown caterpillar on it 5. Full-grown caterpillar, dorsal view 6. Damaged fruit cut open showing pupa inside 7. Pupa 8. Butterfly in repose 9. Female butterfly with wings expanded, wings on the right are those of male.

(*Proc. 2nd Ent. Meeting*, p. 232)

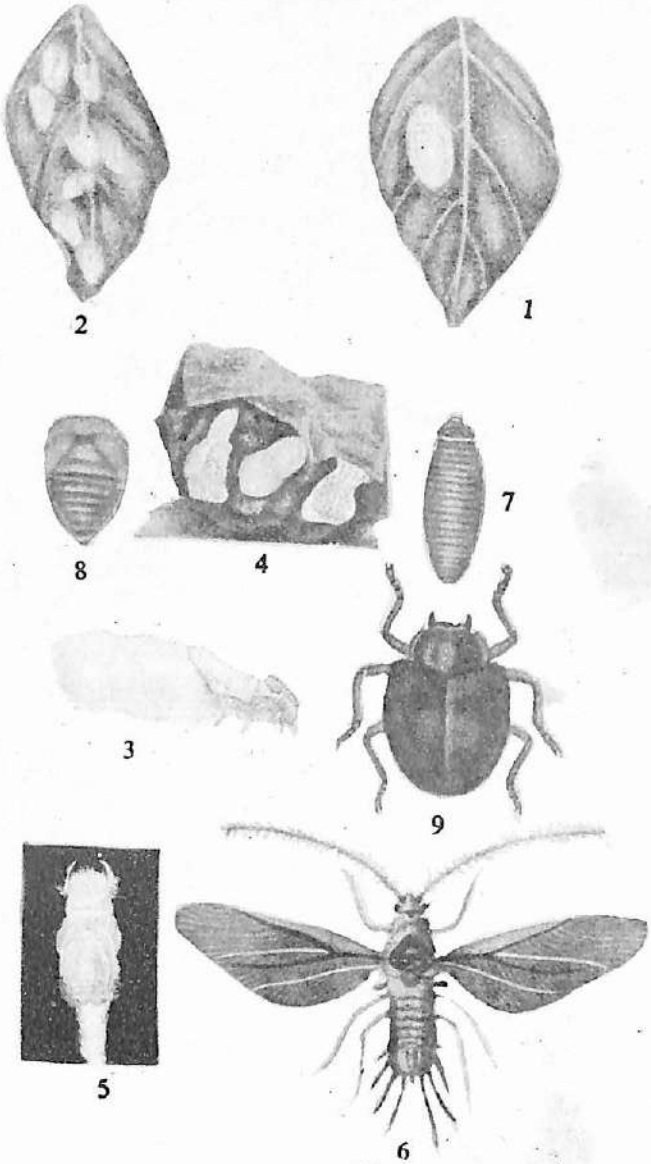


Plate XXXVI—MANGO MEALY BUG

1. Adult female after the last moult 2. Exuviae of nymphs 3. Female showing ovisac 4. Females laying eggs under a piece of brick 5. Male pupa 6. Male imago 7. Coccinellid larva 8. Coccinelled pupa 9. Coccinellied imago. These beetles (7,8,9,) specially prey upon this mealy bug.

(*Indian Insect Life*, Plate LXXXIV, p. 760)

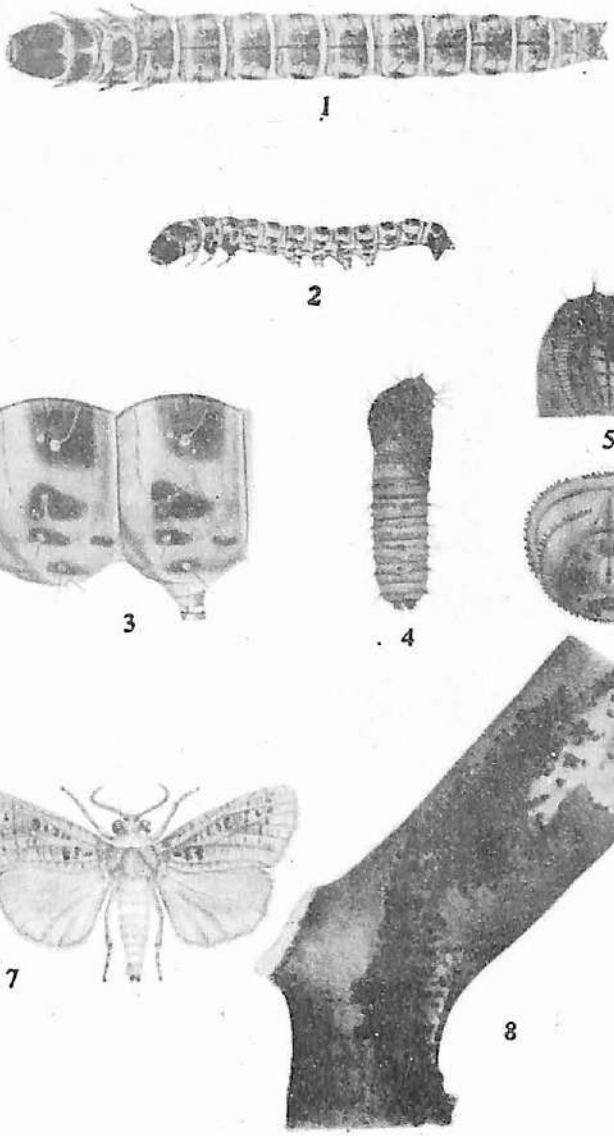
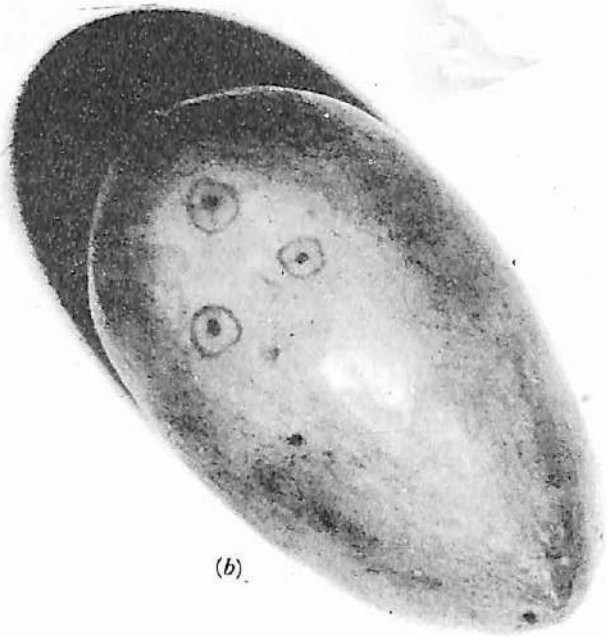


Plate XXXVII—BARK-EATING CATERPILLAR

1 & 2. Larvae, full-grown 3. Second and third abdominal segments of larva 4. Pupa 5. Ventral surface of Pupa 5. Apex of abdomen of Pupa 7. Moth 8. Branch showing masses of excrement and webbing with which it covers the bark on which it feeds.

(*Some South Indian Insects*, p. 453)

(*a*)



(*b*)

Plate XXVIII—MANGO STONE WEEVIL

(*a*) Adult

(*b*) Mango fruit with three characteristic spots (enclosed in separate circles drawn on the mango surface) where the female weevil deposited its eggs and covered them with some secretion.

(Courtesy:Dr. S.R. Wadhi Division of Entomology I.A.R.I., New Delhi)

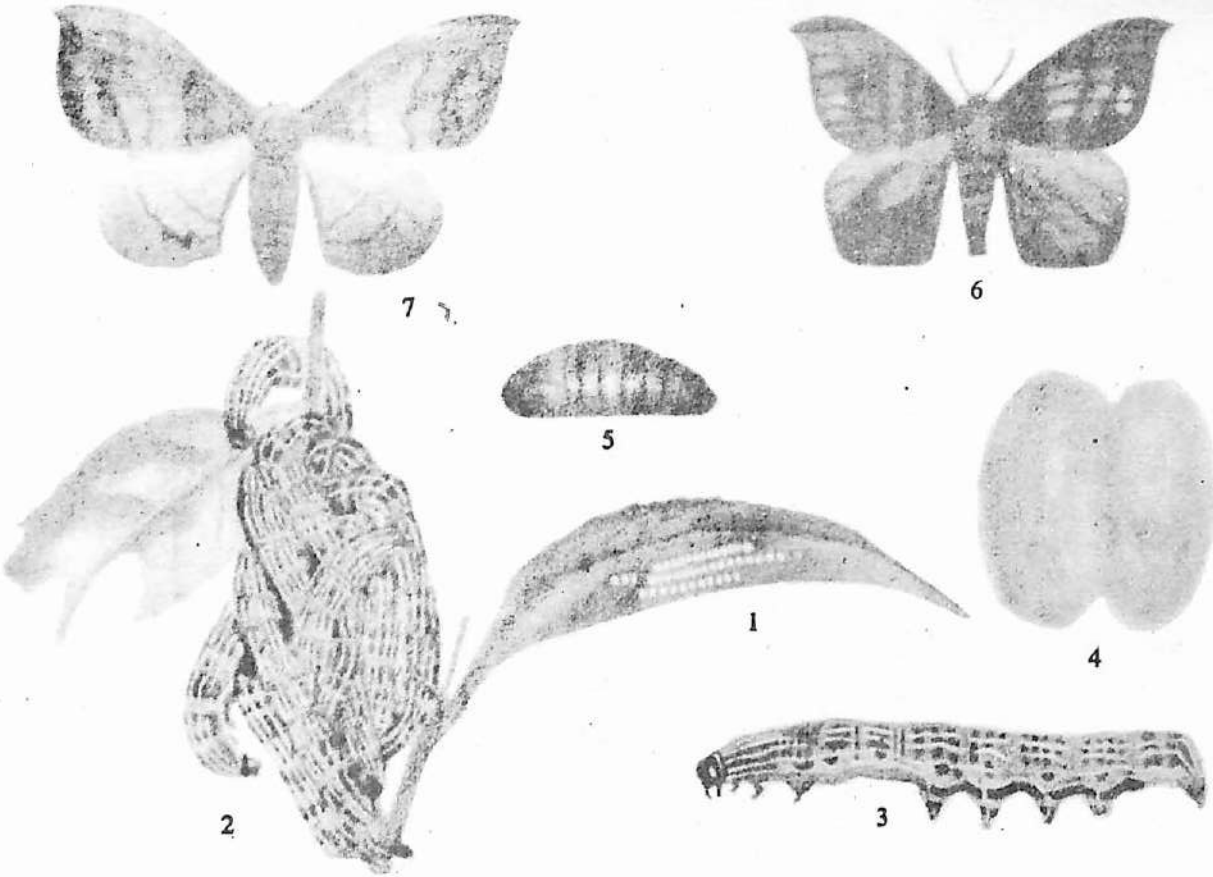


Plate XXXIX—THE BUNCH CATERPILLAR

1. Egg cluster 2. Cluster of Caterpillars 3. Caterpillar 4. Cocoon 5. Pupa 6. Male Moth 7. Female moth

(*Tea Research Association Tocklai Experimental Station Memorandum No. 27.* Plate I)

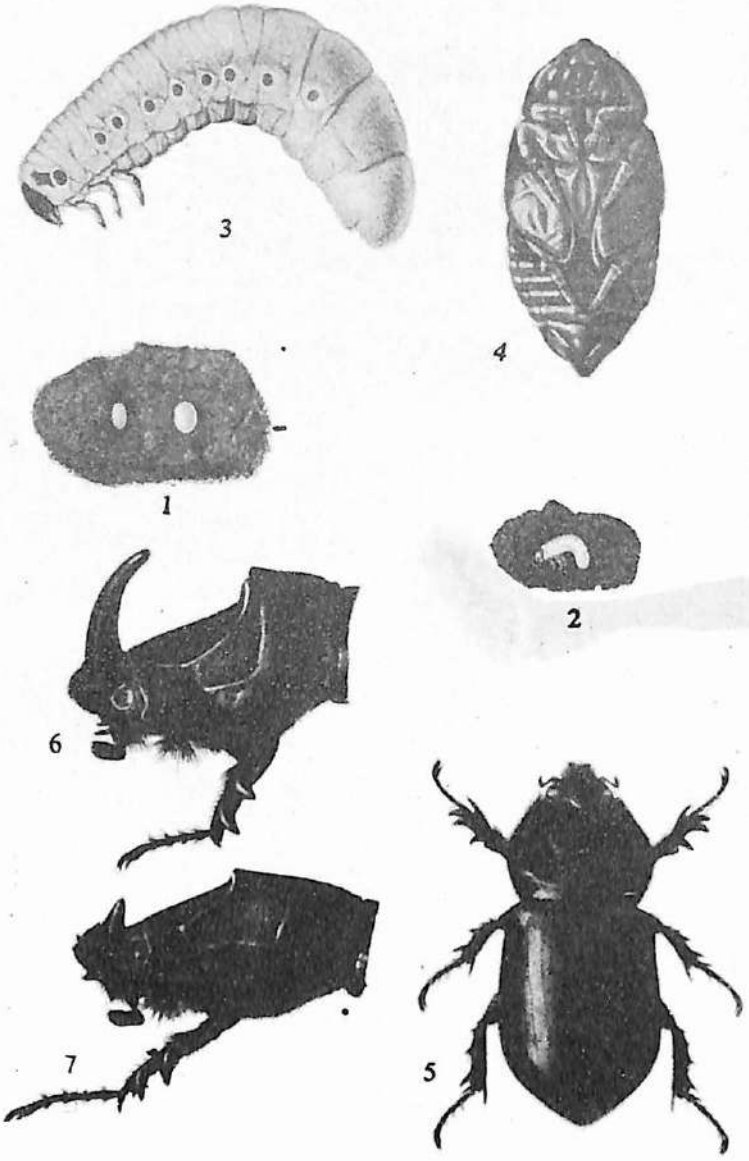


Plate XLII—RHINOCEROS BEETLE

1. Eggs 2. Young larva 3. Full-grown larva 4. Pupa 5. Beetle 6. Side view of head of male beetle 7. Side view of head of female beetle.

(*Some South Indian Insects*, p. 285)

peculiar mode of life. The chief peculiarity of these insects is that their larval stages live in self-made cases which consist primarily of the silk produced by the larvae and vegetable matter of various sorts. The structure and size of these cases are conspicuous characteristics of each species and they also are responsible for the different common names by which they are referred to. Thus, the name faggotworm is applied to those species in whose cases thorns or pieces of twigs of almost equal length are so incorporated that the case looks like a bundle of sticks. The cases of other species look like bags of different shapes and sizes and they are referred to as bagworms. The cases of basketworms are quite large and incorporate in their walls larger pieces of leaves of their food-plant ; the result is that these cases actually give the impression of rough baskets.

The opening of these cases is generally provided with a diaphragm with an aperture in the middle. The larva protrudes its anterior region including its thoracic legs through this opening and crawls about dragging along its case which is firmly held by the hind end of its body. It generally feeds on leaves but often it prefers mature lower leaves to young leaves in the upper portion of the tea-bush. A few species prefer bark to leaves. However, the greatest damage is done to the bush after pruning when the pest attacks the bark and often girdles the young stem which instead of producing young succulent foliage after pruning gets dried up and in severe cases the whole bush may thus be killed.

The main peculiarity from the entomological viewpoint is that in the adult stage the male is a small delicate moth with dusky or hyaline wings, with prominent pectinate antennae, but with the proboscis absent, while the female is little more than a bag of eggs with no wings at all ; hardly any of the adult characters are well-developed in the case of the female ; it is more chrysalis-like than an adult insect : it continues to remain in the larval case. The male moth is very rarely met with ; it comes out generally after dusk, seeks out the female in the larval case, impregnates the same and dies soon thereafter. After fertilization, the female begins to lay eggs within the larval case itself. In some cases, parthenogenesis is also reported. Each female often lays a large number (500 to 1,000 or more) of rather small eggs. This process is like emptying a sack

of its egg-content, the female shrinking as the eggs are laid. The eggs hatch in 10 to 15 days after oviposition. The small young larvae creep out of the mother's case and begin to feed on the leaf-tissue. The shape of the larvae is peculiar in the sense that the anterior part of the body, i.e. the thoracic region is broad and massive, while the posterior region is tapering and it is often kept raised. The most effective distribution takes place at the stage when the larvae are still very small. Soon each larva begins to construct its own characteristic protective case according to the species to which it belongs. The larval period lasts eight to ten months. When full-grown, the male larva closes its case after firmly fastening it to any available twig by means of a strong silk cord, and pupates therein with head downwards. After a few weeks' pupal period, the male moth emerges through the lower end of the larval case. The female larva also fastens its case to some twig like the male and then moults and undergoes a period of rest but remains only a sort of vermiform sac with a genital opening.

There are many species of psychids in India but only those attacking tea plantations have been reported to cause serious concern at times. As regards control, the most rational approach is to get the cases collected manually, particularly soon after pruning is done. The collection should be so timed that only empty cases are not uselessly removed. Chemical control can also be resorted to but in this case it should be made to coincide with the emergence of the just-hatched larvae. Also, it should be kept in view that the larvae prefer mature leaves on the lower part of the bush which also should be thoroughly treated.

MOSQUITO BUG

(*Helopeltis theivora* Waterhouse)

(*Plate XLI*)

The genus *Helopeltis* was formed in 1858 by Signoret for an insect found by Antoine Dohrn in Sri Lanka. In due course, this genus acquired much more prominence than any other genus of the

family Miridae (Capsidae) because some of its members were found to be the most serious pests of a number of tropical cash crops like tea, cinchona and cocoa. Of these *Helopeltis theivora* Waterhouse which is commonly known as the mosquito bug was recognized to be the worst insect pest of tea plantations. For detailed early account on these insects, reference should be made to the large contribution by H.H. Mann (1908) (*Mem. Dep. Agri. India* I: 275-337). In recent years the relative importance of this pest has considerably decreased as it is now fairly easy to kill this pest with the help of modern insecticides.

These bugs suck out the sap from leaves and young shoots of the tea bush. The point at which this sucking is carried out first shows a pale area and generally a tiny drop of liquid comes out from the point at which the insect has penetrated its proboscis. Later the extreme edge of the area and the central spot turn brown and the brown colour gradually extends all over the area until the patch shows up as a light-brown spot. This gradually darkens until it becomes absolutely black and by then the texture of the patch has become hard and dry. By the coalescence of a large number of such patches on the leaf, the whole leaf becomes black and shrivelled and eventually falls off. But the damage does not stop here. The discolouration extends down the centre of the shoot and in severe cases new shoots get killed. When one shoot has been killed, the bush throws out another which is likewise killed off, and in badly-attacked tea plants there are often broom-like growths of blackened shoots at the top of the branches, and the bushes look as if they have been scorched by fire. This explains why this trouble has been referred to as the "*mosquito blight of tea*". Like most other bugs, both the nymphs and the adults damage the plant.

The pest has been reported from India, Indonesia and Indo-China. The adult bug is capable of agile flight. It is a slender insect 6 to 8mm in length, with a yellowish-brown head and abdomen, a dark-red thorax, and long dark appendages. The prothorax has a prominent and characteristic clubbed horn. The elongate and sausage shaped eggs are also peculiar in possessing two filamentous long processes which remain jutting out from the tender plant-tissue in which the eggs are embedded by the female. The eggs are

laid practically in all tender parts of the plant and often they are also laid in the broken end of the plucked shoot. This habit of laying eggs in the ends of shoots from which leaf has been plucked ensures the safety of the egg from any chance of being removed by pluckers. The incubation period varies within wide limits (5 to 27 days). The freshly-hatched nymphs are rather spidery in general appearance due to their elongate appendages. They undergo five moults to become adults and the time required for the completion of one generation varies from about two weeks in June to eight weeks or more in the cold weather. Not only is the adult a good flier but it is also carried to long distances by wind. In fact, the insect tries to avoid a strong wind. All the same, a sudden outbreak can result due to an air-borne population. Also, the pest has several alternate hosts.

The control of the insect is now quite easy with the help of any of the good contact insecticides.

The present-day problems of controlling this pest are mostly of an organizational nature, depending on the timely availability of men and materials. The choice of the insecticide has to depend mainly on considerations of insecticidal residues which have to be kept within the tolerance limits fixed for different insecticides.

Suggestions Regarding Control Schedule

Among the very large number of pests infesting tea plantations, the mosquito bug used to be considered as the most destructive. Now with the development of various potent insecticides this pest like many other bugs is fairly under control and the emphasis has shifted to other insects. In fact, the development of acaricides being slower than that of insecticides, the first place in the order of importance among the tea pests has gone to the red spider mite and other mite pests. However, taking every aspect into consideration, the strategy of pest control in tea plantations should keep in view the following points:

(*a*) The problem of pesticidal residue is of utmost importance. Leaf decoction is consumed; hence, any contamination on the foliage is likely to be directly harmful. Many importing countries have their own stringent regulations against pesticidal contamination of tea.

(*b*) The taste of tea is a very important and sophisticated item to be reckoned with; any tainting of tea leaves is likely to affect the trade very adversely.

(*c*) On the other hand, there are several pests for the control of which a persistent pesticide is needed.

(*d*) Fortunately, however, there are a number of serious pests the control of which is quite feasible by mechanical methods.

Keeping all these points in view, it is advisable to plan the control schedule somewhat on the following lines:

(1) Regular campaigns should be organized for the collection and destruction of such stages of various pests as can be easily located. For example, such a campaign can be organized for the collection and destruction of bunch caterpillars, bagworms, faggotworms, loopers, lobster caterpillars, leaf-rollers, leaf-webbers, nest-forming caterpillars and several other large-sized larvae feeding externally. The same campaign can deal with as many of these pests as may be present at one time. Such campaigns at suitable intervals, if carried out properly and in time, may obviate the use of insecticidal treatment for their control.

(2) Insect pests are of much more varied habits than acarine pests and several of them keep themselves in comparative safety against insecticidal applications. Hence a persistent insecticide is needed. It is advisable to choose a persistent insecticide involving the least residue hazard. Some insecticides like carbaryl and endosulfan have come into the market which are nearer to these requirements.

(3) The red spider mite and other mite pests are external feeders and they can be easily controlled by a good contact acaricide. We can easily avoid a persistent acaricide and restrict our choice to such chemicals whose residue disappears readily.

Thus the overall strategy should be to nip the insect pests in the bud as far as possible by timely campaigns of mechanical control, to use non-persistent acaricides against acarine pests and only if very much necessary to use a persistent insecticide involving least residue hazards.

Pests of Coffee Plantations

There are more than a dozen pests of the coffee plant in India.

However, only two important and interesting pests of the order Coleoptera are being described in the following pages.

WHITE STEM-BORER

(*Xylotrechus quadripes* Chevrolat)

This is a longicorn beetle belonging to the family Cerambycidae, the main characteristic of which is that the antennae are long and their bases are partly encircled by the eyes. The species attacking the coffee plant has been a subject of much discussion and investigation since as early as 1838 and it has been considered to be the most destructive pest of coffee. It has been reported from India, Burma, Sri Lanka, Indonesia and the Philippine Islands. It has found a very favourable host in Arabica coffee which was introduced into India about A.D. 1600. It is an example of an ordinary indigenous species which has found abundance of a cultivated plant in which it can breed well and has thus become a serious pest. It is the larval stage that acts as a stem-borer. The young plants infested by the pest may at times gradually succumb completely to the attack and even older plants get seriously damaged; the affected branches wilt and easily break. In cases of severe infestation, a sizeable proportion of the plantation falls victim to this infestation year after year and in due course the plantation may have to be abandoned or replantation may have to be resorted to.

The adult is a blackish brown beetle a little more than a centimetre in length with three pairs of pale stripes running obliquely across the elytra. It lays eggs in the cracks and crevices of the bark of the main stem or the primary branches of comparatively young plants. Hatching takes place in about 10 days and the larva first feeds on the bark and then bores into the woody tissue which it continues to tunnel in all directions for a period of about 10 months. When full-grown, the larva is about 1·5 cm with rather a broad head and thorax region and a rather tapering abdomen. Before pupation, it cuts out a circular exit hole for the future adult stage to come out. Pupation takes place inside the stem in a pupal chamber which is near the exit hole. The pupal period lasts about

a month after which the adult beetle emerges and starts the next generation.

It will be seen from the above that only one generation can be completed during the year. All the same, there are two distinct periods for the adult emergence and flight—the one during April-May and the other during September-December. During these seasons the beetles prefer a dry warm and rather bright weather for their flight and oviposition.

Also it is clear from the life-history of the pest that it is the larval stage which does the main damage and it remains for most of its existence quite out of the reach of pesticidal sprays or dust. The egg and adult stages have an external existence but against the former there are very few, if any, effective poisons and the latter remains flying from plant to plant. Taking these specific characteristics into consideration, the rational control operations suggested against this pest are:

(*a*) *Detection, collection and destruction of borer-affected shoots*: The shoots infested by the pest often have a number of marked ridges across the bark. If these are scraped, the borer activity can be easily detected. Hence this mechanical control is suggested as a regular routine operation well in advance of the periods of adult emergence. If this operation is carried out late, it will be altogether useless because the pest will have already emerged and there will be no point in destroying the affected shoots which do not contain the pest larvae or pupae.

(*b*) *Treating the stem surface with a strong persistent insecticide which may kill the adults before they lay eggs*: This should be carried out very near the flight period so that it may be quite effective on the just-emerged adults. The proper time can be fixed by a kind of sample survey to determine the advanced stages of pupae from which the adults would emerge soon thereafter. The application of the insecticide may be done by swabbing.

SHOT-HOLE BORER

(*Xylosandrus compactus* Eichh.)

This pest has also been described under the name *Xyleborus*

morstatti Hgdn. The basis of the common name is that it produces a large number of pinholes in the bark generally on the underside of the tertiary branches of the coffee plant. Unlike the stem-borer, this inscet has a decided preference for robusta coffee of which it is considered to be the most serious pest. Both the larval and adult stages tunnel the bark and this tunnelling results in wilting, leaf-fall and final drying up of the affected shoot by a process similar to die-back disease. There is discolouration of the area around the shot-holes. Sometimes pathogenic infection also gets involved and hastens the death of the affected shoot.

This insect is quite interesting; it belongs to a group of ambrosia beetles the larvae of which are reared on certain specially cultured fungal beds. This fungal food is called ambrosia. The female beetle provides a carefully prepared layer of chips and excreta on which the fungus develops. The details regarding the manner in which the fungal inoculum is carried from plant to plant are quite interesting and differ from species to species. These beetles are of great interest because of the varying grades of their social habits, particularly their sex-relations. There are species with altogether unorganised polygamy, with organized polygamy and finally with specialized monogamy. From the economic point of view, these insects are generally referred to as bark beetles (Scolytidae) which cause much concern to foresters.

The adult stage is a short cylindrical beetle of a dark-brown colour. It bores into the bark of generally tertiary branches and lays eggs in the tunnels thus made. One individual can lay up to 50 eggs or more. They hatch out generally in a little more than a week and the white apodous larvae feed on the ambrosia developing on the inner lining of the tunnels made by the adult. The larval period lasts about three weeks and pupation takes place within a pupal cell which is a slightly enlarged portion of the larval galleries and which is connected with the exit hole of the future adult. The pupal period lasts about a week and a half. Thus the whole life-cycle takes five to six weeks, depending on the environmental temperature.

Because of the comparatively short life-cycle and repeated gererations of the pest during the year, it often quickly assumes quite serious proportions. The only rational approach against such

an enemy is to cut and destroy the affected shoots as soon in the season as the infestation is detected. Also a thorough treatment with a strong persistent insecticide acting both as a contact insecticide and as a stomach poison is bound to have a combined preventive and curative effect. The ecological precaution suggested against this pest is to keep shade over the plantation as thin as possible. Good drainage and maintenance of healthy nutritional status of the soil increase the plant's tolerance to the damage done by the pest.

Pests of Coconut Plantations

Over 750 species of insects have been recorded from coconut plants in different parts of the world and of these more than 100 are from India. The two of them described below are of greatest concern to coconut growers in India.

RHINOCEROS BEETLE

(*Oryctes rhinoceros* Linnaeus)

(*Plate XLII*)

This is one of the most destructive pests of the coconut palm and it is distributed practically all over the coconut-growing areas of the world, e.g. India, Sri Lanka, Malaysia, Burma, Indonesia and the Philippines. It got introduced into the Pacific Islands during the first decade of the present century. In India it has been the experience that at least one spathe in each tree is damaged by this beetle every year when a healthy palm puts out on an average 10 spathes per year. Sometimes the young plant succumbs to the attack of this pest. In some of the Pacific Islands, mortality due to this pest has been up to even 50 per cent.

The rhinoceros beetle is a pest which is harmful only in the adult stage which feeds on the crown of the coconut trees, while the larval stage feeds on decaying organic matter. The adult is a large black beetle the length of which varies from 35 mm to 50 mm and the breadth from 14 to 21 mm. The head bears dorsally a

large erect horn which is the basis of the common name of rhinoceros beetle for this insect. The ventral surface has a reddish-brown tinge. It feeds voraciously on the unopened central whorl of leaves in the crown of the coconut and when this whorl opens out, the eaten portions of the leaf show up as large chunks of leaves as if cut by a pair of scissors. Sometimes the growing point of the plant is damaged, resulting in the death of the plant. The damage also paves the way for further fungal and bacterial infections.

The mother-beetle lays eggs in manure heaps, compost material and decaying vegetable matter including decaying trunks of the coconut and other palms. A single individual on an average lays more than 100 eggs. The eggs are quite large (2·5×3·5mm) which also swell up further during development. They hatch after a week or two and the freshly-hatched larvae, about 7 mm in length, begin to feed on the decaying material in which they find themselves from the very beginning. The full grown larva is quite plump and fleshy and it is generally arched in posture, the convexity being on the dorsal surface. At times this curvature is so much that the cylindrical elongate larva forms a full ring, t e cephalic and caudal ends almost touching each other. There are three instars during the whole larval period which lasts from two and a half months to more than six months. For pupation the larva burrows somewhat deeper in the material on which it has been feeding, the depth depending on the moisture-content of the breeding media and environmental humidity so as to avoid desiccation. At times the pupation may take place at depths up to 120 cm. The larva prepares the pupal cocoon in which the pupa later lies free on its back. Damage to the cocoon often leads to the death of the pupa. The pupa is brown in colour and it varies from 50 mm to 70 mm. The pupal period lasts for two to four weeks and even after emergence from the pupal shell, the beetle remains in the cocoon for about 11 days before coming out of the soil. The adult emerges as a soft tender creature which is light brown in colour but this colour soon changes to dark brown and finally to black The adults start egg-laying about three to nine weeks after emergence.

There are a number of natual enemies, but for these the damage by this pest would have been much more serious than it actually is. These enemies include pathogens, insect parasites and predators as

well as the higher animals like frogs, toads, birds, pigs, rats, squirrels, etc. The size of the insect both in adult and immature stage is big enough to make it worthwhile even for large animals to hunt and prey upon them. This predatory fauna would have kept the pest much more in check but for the fact that the larval and pupal stages live quite deep in the manure heaps.

In view of the fact that the pest spends its egg-to-pupal stage in manure heaps and other decaying matter, the most rational attack against this species is the maintenance of proper sanitation in the cocount plantations and keeping the area clean of decaying matter which should be kept together in selected places as compost and thoroughly treated with a persistent insecticide at suitable intervals. This simple precaution will not only considerably reduce the breeding area to a manageable size but also the manure, etc. kept at selected places will act as traps for the pest which will be attracted thereto for laying eggs. Such breeding-traps constitute one of the recognized recommendations against the rhinoceros beetle but it is obvious that cleanliness of the place is essential for the success of such breeding-traps; otherwise even a very small collection of decaying matter on an unspotted place will attract the pest and it will then be impossible to tackle the problem effectively.

So long as it is not possible to organize the clean-up campaign suggested above in a sizeable area of several square kilometres, the method suggested for individual gardeners is to hook out the adult while it is feeding in the crown. There is a special metallic rod for this purpose which is 75 cm in length with a hook at one end and a grip-ring at the other. By experience it is possible to insert this hook into the crown in such a way that it pierces the body of the beetle which is pulled out and destroyed. There are a number of professionals who go round and climb trees and hook out the beetles for some remuneration. After removing the beetle, the hole is filled with a mixture of sand and a suitable insecticide. The same mixture is also plugged into the axils of the leaves of unattacked plants, so that the adults may get poisoned when they visit the crown for feeding therein.

BLACK-HEADED CATERPILLAR

(*Nephantis serinopa*, Meyrick)

(*Plate XLIII*)

The larval stage of this pest is a voracious feeder of coconut leaves and the damage done to the foliage is so severe that the vitality of the whole tree is lowered and the yield is very adversely affected. Even to a casual visitor, the gardens suffering from the infestation of this pest present a very gloomy picture.

The species is distributed practically in all the cocount-growing areas of India, Burma and Sri Lanka. Besides cocount, it attacks a number of both cultivated and wild species of palms, e.g. palmyra palm, wild date, etc. According to available records, it has been causing serious concern from the beginning of the present century.

In the adult stage, this pest is a medium-sized moth belonging to the family Cryptophasidae. Its body length is 10 mm to 15 mm and its wing-span 20 mm to 25mm. The colour of the wings is pale greyish with certain black spots on the forewing. There is a prominent sexual dimorphism, the hind-wing in the male has a prominent tuft of hair at its hind base. They are nocturnal in their activity but unlike many other moths they are not attracted to light. Their activity is mainly confined to a short period after dusk. During the day they remain resting either on the trunk of the tree or on somewhat dried and drooping leaves.

The eggs are generally laid on the tips of the older leaves; they are so inconspicuous that they are not ordinarily noticed. One individual may lay more than 250 eggs, although the average works out to about half that number. Fresh eggs are creamy in colour but these become pink after embryonic development. The incubation period is generally less than a week.

The freshly-hatched larva is only about 1·5 mm but it grows to ten times this size by the time it is ready to pupate. As the common name suggests, the head of the larva is blackish and the rest of the body changes from pale white to start with to light green in the end. There are five reddish brown stripes—one on the dorsal side and two on each of the lateral sides. The larva right from the

beginning is a voracious feeder but before it starts feeding, it constructs a silken gallery on the leaf and feeds on the leaf-tissue within this gallery. Later, bits of the leaf are added to the silken wall and the length of the gallery goes on increasing with the increase in the feeding activity of the larva.

When full-grown in a period of about six weeks, the larva enters the pre-pupal stage of comparative inactivity when it does not feed but prepares a cocoon at a suitable corner of the larval gallery. Thereafter, it pupates within the cocoon into a chrysalis which is somewhat dorsoventrally compressed. The adult emerges about 12 days after pupation.

Nephantis serinopa has a number of natural enemies in the form of insect-parasites, parasitising mainly the larval and pupal stages, insect and mite predators and fungal and bacterial diseases. The larval gallery affords quite a good protection during dry weather but it seems to turn the situation specially in favour of parasites and disease-causing organisms during the rainy season when the larval gallery gets wet. Heavy rain also seems to bring down the pest population by mechanically washing down both the adult and the immature stages. The interaction of all these biotic and abiotic factors is reflected in the seasonal history of the pest. The peak activity of the pest is generally during the dry months of March, April and May and it may extend if the monsoon is delayed. The pest population gets very much thinned down during the rains but the pest activity begins to pick up as soon as the rains cease. At that time of the year, however, the insect-parasite activity becomes comparatively more effective and this situation persists till about January the following year. Thereafter the pest activity increases and the parasite population dwindles with a rise in temperature and fall in humidity till the peak activity of the pest is reached about the month of March.

As regards the control of this pest, two points which have to be specially borne in mind are; (*a*) that the pest activity is easily noticeable right from the beginning, and (*b*) that the natural enemies of the pest play quite a significant role in the seasonal incidence of the pest. Hence proper integration of mechanical, biological and chemical control is advisable. As the pest activity starts every year from quite a low population in January, a

campaign should be organized during this early period to nip the trouble in the bud by cutting off and burning the leaves showing fresh infestation along with the pest. This will go a long way in checking the population build-up of the pest and no further remedial measures may be found necessary if this mechanical campaign is properly executed. However, if a serious infestation is noticed is some pockets, it may be controlled by insecticidal treatment, particularly during the months March to May-June, when the pest population is generally so high that no risk can be taken with any control measure less drastic than a strong insecticide. Later in a season, i.e. after the rains, it is advisable to supplement the natural biological control by large-scale release of parasites. These releases will be much more useful because this is more a season for the parasites and the pest population is at a level when biological control can be depended upon. This intensification of biological control will reduce the magnitude of the problem during the following year when mechanical control will become more feasible. In this way, chemical control operations can be first minimised and ultimately avoided.

CHAPTER XII

PESTS OF SPICES, NARCOTICS AND DRUGS

THE extent to which insects as a class can adapt themselves is well illustrated by quite a large list of insect pests of plants belonging to the economic groups of condiments, spices, narcotics, drugs, etc. Plants belonging to these groups produce and/or contain a vast variety of chemicals of very high physiological activity which animals generally cannot relish or even tolerate in more than very small quantities in their food. All the same, plants belonging to all these groups have their own insect pest problems. In other words, a large number of insects can live and breed on such plants. In fact, a number of plants contain and produce highly effective insecticides and yet they have their own serious insect pest problems. One of the best examples is afforded by tobacco which contains one of the most potent insecticides, nicotine, and yet it has serious insect pests of its own, although various tobacco preparations have been used as insecticides for a very long time. Apparent anomalies in some of these cases have been explained by advances in our knowledge on the mode of action of these toxic compounds. The following paragraphs contain only very brief references to the most important pests of such groups of plants.

Tobacco, the source of the insecticide nicotine, is subject to devastation by (1) the tobacco caterpillar (*Spodoptera litura* Fabricius) (2) the cutworm (*Spodoptera exigua*), (3) the stem-borer (*Phthorimoea* sp.), (4) the gram caterpillar (*Heliothis armigera* Fabricius), the tobacco aphid and many others under field conditions while the cigarette beetle (*Lasioderma serricorne* Fabricius), is the most serious pest of tobacco in factories and cigar stores.

Ganja, the well-known intoxicant, is attacked by pests listed at 1, 2 and 4 in the above paragraph besides a number of others. Cinchona, the source of quinine, is infested by a number of cockchafer beetles and grubs.

The mint plant (*Mentha arvensis* Linnaeus), the source of menthol, a chemical of great pharmaceutical value is infested by the

pyralid (*Syngamia abruptails* Walker), the Noctuids *Spodoptera exigua*, *Autographa* (*Plusia*) *nigrisigna*, *Euxoa segetum* and the Arctid (*Spilosoma obliqua* Walker), besides a number of others. Another plant of great medicinal value known as *khurasani ajvayán* (*Hyoscyamus niger* Linnaeus) has among its pests two species of *Heliothis* including *H. armigera* and the polyphagous aphid, *Myzus persicae* Sulzer. The plant *Atropa belladonna* Linnaeus, the source of the well-known medicine belladonna, has among its chief pests the equally well-known cutworm, *Ochropleura flammatra*. The plant *Rauwolfea serpentina* Benth., which in recent years has attracted much attention for its medicinal value, is attacked by the sphingid larva (*Dielephila nerii* Linnaeus).

The plants of the genus *Chrysanthemum*, the source of the most effective and sought-for insecticide pyrethrum, are attacked by *Spilosoma obliqua*, aphids and termites. The poppy crop, the source of opium, has among its enemies a number of cutworms, grasshoppers and beetle pests.

The turmeric plant used as a spice is damaged by a shoot-borer (*Dichocrocis punctiferalis* Guenee) and by a butterfly larva (*Udaspes folus* Cramer), some thrips, lace-wing bugs and scale insects. Ginger is also attacked by the turmeric shoot-borer. The coriander crop is attacked by the caterpillar *Spodoptera exigua*, some stink bugs and plant lice. The peppervine has an important pest in the flea beetle (*Longitarsus nigripennis* Motschulsky), two species of scale insects and a mealy bug. The cardamom has a serious enemy in the turmeric shoot-borer besides the cardamom thrip and the scolytid beetle. Both turmeric and ginger are seriously infested by *Lasioderma serricorne* under storage conditions. (Plate XLV)

The foregoing paragraphs will show that even those farmers who may be growing crops for purposes of poisons, insecticides, drugs, narcotics etc. or plants of a highly sophisticated nature like various spices, have also their own important enemies in the insect world. It will also be interesting to note from the foregoing account that some species like *Spodoptera exigua*, *Heliothis armigera*, *Myzus persicae* etc. appear in the lists of pests of several of such highly specialized plant species, implying that some of these are specially adapted to such a vast variety of dietary material. *Lasioderma serricorre* is quite interesting from this point of view. Hence a short

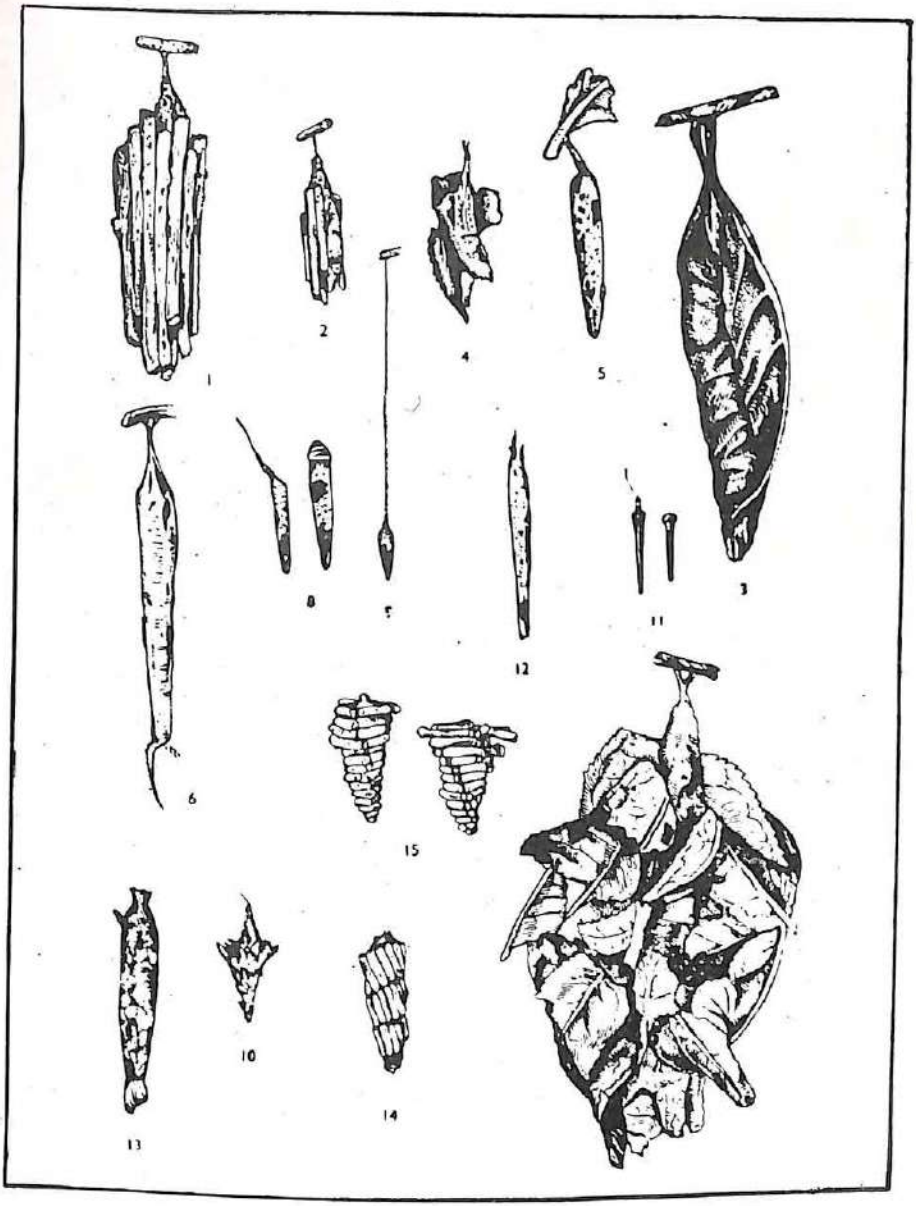


Plate XL—Psychids

1. *Clania cramerii* Westw 2. *Clania destructor* Dudg 3. *Clania sikkima* Moore 4. *Clania antrami* Hmps 5. *Clania mahanti* Das 6. *Clania vaulogeri* Heyl 7. *Mahasena theivora* Dudg 8. *Metisa plana* Wlk 9. *Pteroma plagiophleps* Hmps 10. *Manatha assamica* Watt 11. *Cathopsyche reidi* Watt 12. *Chalioides ferevitrea* Joan 13. *Dappula tertius* Templ 14. The Spiral Faggot Worm 15. *Orophora triangularis* Das.

(From *Pests of Tea in North-East India and their Control.* Tea Research Association, Tockali Experimental Station, Memorandum No. 27.)

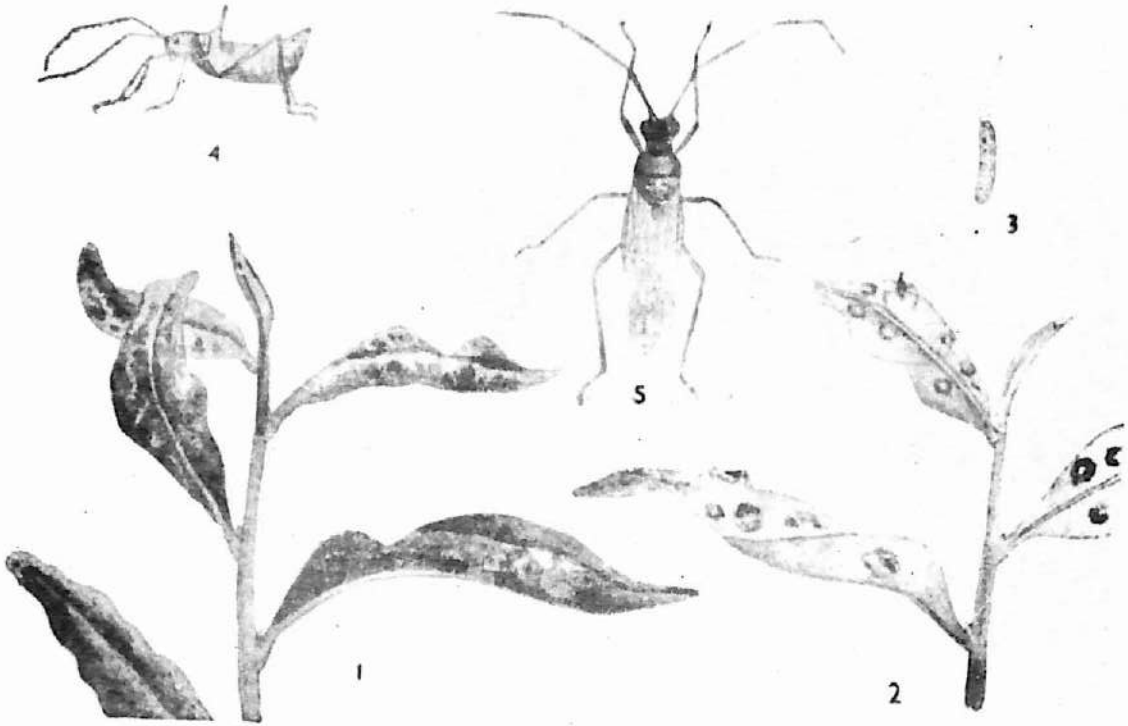


Plate XLI—Tea Mosquito Bug
(Helopeltis theivora Waterh.*)*

1. Leaves showing damage 2. Leaves showing fresh punctures 3. Egg 4. Nymph 5. Adult.

(From *Pests of Tea in North-East India and their Control.* Tea Research Association, Tockali Experimental Station, Memorandum No. 27.)

account of this highly polyphagous pest is given below as an example.

CIGARETTE BEETLE

(*Plate XLIV*)

Lasioderma serriocorne Fabricius which is commonly known as the cigarette beetle, infests under storage conditions a vast variety of commodities including such specialized material as ergot, turmeric, tobacco, ginger, hellebore, liquorice, opium, belladonna, red pepper, paprika, saffron, cumin seed, strychnine, insect powders containing pyrethrum, nutmeg, aniseed, etc.

This species is a member of the family Anobiidae of the order Coleoptera. It is distributed practically all over the world. The adult is a small robust beetle, reddish yellow in colour and about 2.5 mm in length. However, its size differs widely according to food material on which it has bred. It is generally quite active, particularly during the afternoon and night. It is also attracted to light. The longevity of the adult is up to four or five weeks or more under certain conditions.

The mother-beetle lays eggs in all kinds of rather hidden safety niches like the space in between the folds of the tobacco leaves, in the folds of cigars and cigarettes, in nooks and corners, in crevices and depressions, in between grains like coriander etc. The eggs are so small that they often escape notice. These are whitish and opaque and pointed at one end, the length being about 0.5 mm.

The incubation period may be as short as four days but it can get lengthened to more than two weeks, depending on the temperature and humidity of the environment.

The larva on hatching out is a greyish white grub about 1 mm in length and its body is covered with a fine hairy coat. The larval period varies within very wide limits; it may be as short as a month and as long as about six months. The full-grown grub is about 3 mm. The feeding by the larvae results in characteristic tunnels running both longitudinally and across the tobacco leaves, cigars, etc. It at times riddles the bales of tobacco leaves. When full-grown, the larva makes a flimsy cell in which it pupates. Although pupa-

tion takes place under a variety of sorroundings depending on the material on which it breeds, the larva makes sure that the adult will have to break through only the flimsy cocoon to get out into the open. The fresh pupa is whitish in colour but it turns brownish later on. The pupal period may be as short as five days but it can get lengthened to about three weeks or so.

As regards control, this pest is quite susceptible to high temperatures and it has been reported that practically all stages can be killed by about 15 minutes exposure to 60°C. Fumigation can also be usefully resorted to after making sure that the fumigant does not react adversely on the commodity which is so varied in nature. Also the question of residue will have to be considered seriously.

CHAPTER XIII

STORAGE PESTS

Pests Common to Several Commodities in Storage

Several hundred insect species have been reported to be associated with stored grains and milled cereals but some 50 of them have been occasionally found to cause serious damage. The five pests described below are considered to be the most serious under Indian conditions.

RICE WEEVIL

(*Sitophilus oryzae* Linnaeus)

(*Plate XLVI*)

This is the most destructive insect pest of grain in the world. It is called the rice weevil only because it was found to be infesting rice when it was described for the first time. Actually, it infests very large varieties of stored grain and is cosmopolitan in its distribution but it is generally much more injurious in warm humid countries.

It is a reddish brown weevil about 3 mm in length and its head has a slender pointed forward projection with a pair of stout mandibular jaws at its extremity. Unlike its near ally, the granary weevil (*Sitophilus granarium* L.), it is a strong flier and it has been known to fly from the godown to the fields in the vicinity where it begins to infest the grain in the field. The life-span of the adult weevil is four to five months. The mother-weevil makes a small cavity in the grain by means of its powerful jaws and then lays in it a small egg which is just plastic enough to fit in the cavity made by the mother who thereafter covers the egg with a gelatinous fluid. The tiny fleshy white legless grub hatching out from the egg bores down into the grain wherefrom it emerges only on reaching the adult weevil stage. The grubs feed rather voraciously on the content of the grain but leave the shell intact. The full-grown larva makes a pupal cell therein. At the end of the pupal period which may last

from a few days to a few weeks the adult bores its way out of the grain. Each weevil lays 300 to 400 eggs and the life cycle is normally completed within about four weeks. Thus several generations are possible during a normal storage season and therefore the severity of infestation and damage goes on increasing with the passage of, time.

From the viewpoint of control, the weakest point in the life of this pest is that it is unable to breed in the grain if the grain moisture content is less than 9 per cent. Hence if one can afford to dry the grain and keep it dry during storage, it is almost certain that the grain will not suffer any damage due to this pest. It may, however, be pointed out in this connection that if the grain moisture is at the marginal level, say between 9.5 per cent and 10 per cent in some pockets of the bulk, the weevil can raise both moisture and temperature by means of water and heat produced by itself and thus create a microclimate suitable for itself. Often serious cases of grain-heating in this way have been reported. If keeping the grain dry is not practicable, then fumigation is the only feasible proposition as soon as the infestation reaches an intolerable level.

LESSER GRAIN BORER

(*Rhizopertha dominica* Fabricius)

(*Plate XLVII*)

This beetle pest (*Rhizopertha dominica* Fab.) is also cosmopolitan in its distribution and very serious in respect of damage to stored grain. In some places it is considered to be next to *Sitophilus* but in other places it is reported to be causing more damage than even *Sitophilus*. It belongs to a family of wood-borers and it is considered to have developed a liking for stored grain when it came in contact with grain as an insect infesting the walls of wooden grain containers. In the adult stage, it is a small polished, dark-brown or black beetle about 3 mm in length and a slender cylindrical body with its head turned down under the thorax. Both the adult and the larval stages are equally injurious to the grain. This species was first described by Fabricius in 1792 from a shipment of seed and

roots carried from India to South America and therefore its original home is said to be India wherefrom it has spread practically to all parts of the world. The adult is a strong flier and can spread with great rapidity.

A few peculiar characteristics of this pest are as follows : (*a*) At times this insect is found near the bottom of bins for which it seems to be well adapted, (*b*) the adults are rather fragile and get damaged by mechanical turning of the grain stored in bulk, (*c*) it can penetrate the sidewalls of wooden bins as it belongs to a family of wood-borers, and (*d*) as a causative agent for heating the grain it is somewhat less effective than *Sitophilus*, the carbon dioxide production by adult *Rhizopertha* being roughly half of that produced by a *Sitophilus* adult ; in fact, in a mixed infestation four *Rhizopertha* are considered to be equal to one *Sitophilus*.

A mother-beetle is capable of laying 300 to 500 eggs which are deposited either near the embryo end on the grain or simply dropped in between grains. The larvae hatching from these eggs are quite active and they soon enter the grain generally near the comparatively soft embryo end and pass the rest of their life therein. Some, however, remain feeding on the powdered starchy material without entering the grain. The larva undergo three or four moults and then pupate inside the grain itself. As a result of larvae feeding inside, the whole grains often get reduced to a sort of mere hollow broken shells. The total life-cycle from egg-laying to adult emergence may be completed in about a month, although this period can be very much prolonged depending on the temperature.

As regards control, the characteristics of this pest are more or less like those of the rice weevil, and therefore similar control measures can be adopted for this pest also.

KHAPRA BEETLE

(*Trogoderma granarium* Everts)

(Plate XLVII)

Although its distribution is fairly cosmopolitan, this pest assumes very serious proportions mostly in warm dry regions. Thus, in

India, its damage is far less along the humid coastal regions than in the interior of the country. Another peculiarity of this beetle pest is that unlike other beetles the adult in this case is harmless and the grain is damaged only by the larval stage. Further, the first attack is generally at the embryo point of the grain but later when infestation becomes heavy, other parts of the grain are also badly damaged. In fact, the grain damaged by Khapra and *Rhizopertha* looks more or less alike.

The adult female stage is a small, rather oval, pale red-brown or black beetle about 2.5 mm in length and with indistinct markings on the wing-covers; the male is almost half the size of the female. One female lays about 125 eggs which hatch into very prominent hairy larvae. The hairs are reddish brown, movable and they are grouped into a number of bundles along the body and a sort of tail at the hind end. The larvae are extremely resistant creatures, resistant to insecticides, resistant to adverse temperatures and humidity and resistant to starvation for months and years. Besides the inbuilt protection in the form of hair and a hard waxy covering on the body surface. the larvae are in the habit of seeking refuge from an adverse environment in various cracks and crevices, concealed places behind broken plasters, in seams and meshes of jute bags, etc. and they can remain alive in such niches for several years without food. In this stage, this insect is probably one of the few most resistant insects. Fortunately for us, however, this extreme resistance gets lost rather suddenly the moment the larva changes even to the pre-pupal stage. The pupal stage generally lasts for only one to three weeks and the adults are ready to start the next generation very soon after emergence. The whole life-cycle can be completed under favourable conditions in so short a time as four weeks but this period can get prolonged to as much as four years under unfavourable conditions.

This pest is most resistant to low humidity and low-moisture content of grain and unlike the rice weevil and *Rhizopertha*, this can breed in grain with so low a moisture-content that the drying of the grain as recommended for the other two pests is of no avail for checking Khapra infestation. On the other hand, the weakest spot in the life economy of the Khapra beetle is that unlike the other two pests, it is highly susceptible, particularly in its egg, pupal

and adult stages, to reduction in oxygen tension. Due to this peculiarity, the Khapra beetle is generally a surface-feeder and it is not able to breed beyond a particular depth below the grain surface. This characteristic can be best exploited for its control because an airtight container is quite a dependable insurance against damage by this pest. As soon as the oxygen in an airtight container is even partially consumed due to respiration by grain or by insects, if the infestation is there, and the oxygen percentage in the air is reduced from about 21 to about 16 the environment inside the airtight container becomes unfit for Khapra-breeding. Of course, if the container is opened frequently and fresh air is allowed to get in, then Khapra-breeding will not cease.

ANGOUMOIS GRAIN MOTH

[*Sitotroga* cerealella (Oliver)]

This pest (*Sitotroga cerealella* Oliv.) is commonly known as Angoumois grain moth simply because it was first described from the French province Angoumois in 1736. It is also referred to as the "fly weevil" in America. In India, it is at times referred to as the paddy moth because it often infests paddy in the coastal regions of India. It, however, also infests wheat, maize, barley, jowar and other cereals.

High humidity and high moisture content of the grain are obviously important prerequisites for this pest. Hence its seriousness under Indian conditions is mostly confined to the coastal regions. Also its infestation generally does not extend beyond a few inches below the surface of stored grain, although in this surface layer the infestation often becomes very serious. All the same, in countries where the moisture content of the grain is generally high, this pest is considered to be extremely serious, probably second only to the *Sitophilus* weevil.

The infestation of this pest starts when the crop is still in the field and the grain is in the milky stage. This infestation continues to increase unchecked right upto the time when the harvest is waiting for threshing. Obviously during these stages it is very easy for the moth to move from ear to ear and lay eggs. This move-

ment gets restricted once the grain is cleaned and stored.

The adult stage is a small moth about 1·25 cm in wing-span, yellowish-brown in colour and with very prominent wide fringes along the wing-margins. It can lay up to 400 eggs which are deposited rather indiscriminately on or in between the grains, on the earheads in the field or on the threshing-floor or in the store. The egg is about 0·5 mm in size, white and oval in shape but soon it turns bright red and hatches within a week or so. The tiny larva crawls about a little and soon finds out a comparatively weak spot, say a crack or an abrasion, through which it enters the grain. Once inside, the larva often turns about and practically closes the entry hole by a silken web. Thus, it begins its larval existence in an environment of plenty and safety and continues in that state till it is full-grown to about 5 mm within two or three weeks. By this time, the grain is practically hollowed of its contents which are replaced by faeces and other refuse. At this stage, the larva cuts out a circular exit hole, leaving over it just a sort of cap which the future moth can easily push off. Thereafter the larva spins a silken cocoon inside the grain and transforms itself into a brown pupa. The pupal period lasts for a week or so after which the moth comes out and begins the next generation. Thus, there can be several generations during a year, depending on the environmental temperature and humidity. As in moths in general, the adult stage does not cause any damage and only the larval stage causes direct harm to the grain. As it is not generally easy to detect the infestation by means of the entry hole, the first indication of the infestation comes rather suddenly when a whole generation of moths emerges and exit-holes become prominently visible on individual grains.

There are a few parasitic and predatory enemies of this pest but they are not of any practical utility.

From the control viewpoint, the weakest spot in the life-economy of this pest is its requirement of high moisture-content in the grain. Hence its damage can be kept under control by proper manipulation of the grain moisture-content. Of course, fumigation can also be resorted to as a palliative.

PULSE BEETLES
(*Callosobruchus* spp.)
(*Plate XLIX*)

Unlike the beetle pests of cereals which belong to diverse families the pulse beetles belong to one rather small family named Burchidae, just as all the pulses belong to one family of plants called Leguminosae. The Bruchids, as these pests are commonly referred to, are small beetles rarely exceeding half a centimetre in size and with very characteristic facies which clearly distinguish them from other pests of storage. Their characteristic appearance is mainly due to their small head with a blunt snout, the femur of the hind leg specially thickened, truncated elytra which do not cover the posterior portion of the abodomen, the abodomen also peculiarly thick-set and serrate or pectinate antennae.

The majority of the Bruchids attack the leguminous pods in the field wherefrom they are carried to storage godowns. However, they do really serious and spectacular damage under storage conditions. Pulse-seeds are often brought out from the storage godowns in a miserably damaged condition, each grain being studed with a number of whitish scale-like eggs or egg-shells and a number of prominent circular exit-holes from which the adult Bruchids have already emerged.

In the field, the eggs are laid on developing leguminous pods either on the outside or inside of the pod and the larvae hatching out from these eggs bore their way up to and into the soft, developing grain inside the pod. Since the larvae are very tiny at the time of boring, the entry hole is generally not only too small to attract notice but it also soon gets healed up. Also the pluse-grain matures earlier than the insect inside and the result is that the grain is harvested and stored in an apparently healthy condition even though the internal infestation may be quite high. That is the reason why the farmer gets a shocking surprise on finding his grain completely spoiled although he has taken reasonably good precautions not to allow insects to get into his stored grain.

Under storage conditions, the beetles often lay a number of eggs on each grain, depending on its size, and these eggs look like yellowish white round scales very prominent against the contrasting

background of the grain surface. The eggs hatch within a few days and the larvae bore into the inner wall of the egg-shell which is in direct contact with the grain surface and then bore into the grain. Thus unlike other eggs those of Bruchids do not show up the exit holes even though the larvae have alrady hatched. Inside the grain the larva feeds and moults a number of times till it is full-grown. Thereafter, it partially cuts a circular disc in the seed-coat which just remains in position and then the larva pupates inside the grain. The pupal period lasts only a few days after which the beetle emerges by further cutting out the circular disc into an emergence hole.

As regards the specific requirments for Bruchids, the species which has been studied shows that it can breed in pulse grain with even less than 6 per cent moisture content. Hence keeping the grain dry does not constitute a dependable insurance against damage by this pest. It is, however, becoming clear that some stages are quite susceptible to reduction in oxygen tension. Thus, from the viewpoint of control, it is more like Khapra than like *Sitophilus*.

Analysis of Grain Storage Problems in India

Grain under storage conditions suffers damage mainly from four sources, viz. rats, insects, mites and micro-organisms. The problems of rats, being basically different from those of the other three, these three can be tackled together first.

The safety of stored grain from damage caused by insects, mites and micro-organisms largely depends on the proper management of three factors, viz. (1) the moisture content of the grain, (2) the availability of oxygen, and (3) the development of temperature gradient within the stored grain. For its rapid development, each of the different insect and mite species requires particular humidity which in stored grains depends on the moisture-content of the grain, a certain percentage of oxygen in the air and a certain range of temperature. The requirements of the micro-organisms are also somewhat similar although some of them are capable of sustaining themselves even in the absence of oxygen. Hence for ensuring the safety of the grain from insects, mites and micro-organisms, all these three factors have to be properly manipulated, firstly, through the design and construction of the storage structures and storage

godowns and, secondly, through storage practices. If, however, these ecological safety measures are not practicable under a particular set of conditions, then recourse to the chemical or physical control of infestation becomes necessary.

(*a*) *Moisture-content* : The moisture requirements of some storage pests are given in Table I. This table will show that if arrangements can be made to maintain the moisture-content of the stored grain below about 8 per cent, then most of the insect infestation can be avoided except that of the Khapra beetle which can be avoided by the proper manipulation of the oxygen content of the air (*vide infra*). The moisture-content has also to be kept low for ensuring freedom from micro-organisms and the quality and viability of most of the grains. The question is how best to manage the moisture-content of the grain. The initial moisture-content before storage can be brought down by sun-drying or by means of different types of grain-driers. But, if this dried grain is stored under conditions wherein it keeps coming into direct contact with atmospheric moisture, it will soon adjust its moisture in accordance with atmospheric humidity. It will also absorb the moisture if the grain is in direct or indirect contact with a moist surface. A third source for the increase of moisture is the metabolic water produced within the grain through insect and/or grain respiration but this source remains insignificant if the above two sources are taken care of. Also at times there is increase of moisture in different portions of the stored grain due to the

TABLE I

Moisture-content of the grains at which different species can breed

Sl. No.	*Insect Species*	*Minimum Moisture Content** (%)	*Optimum Moisture Content** (%)
1.	*Trogoderma granarium*	0 to 1.9	11.5
2.	*Sitophilus orvzae*	9.5 to 11	14 to 14.7
3.	*Rhizopertha dominica*	9.10	11 to 14
4.	*Tribolium castaneum*	10	11.5 to 16
5.	*Corcyra cephalonica*	9	15 to 20
6.	*Cadra cautella*	10	16

*These figures represent the range in which the findings of different workers vary.

development of a kind of temperature-gradient within the grain, the moisture evaporating from the warmer portions and condensing in the cooler spots of the grain stock (*vide infra*). All these points have to be kept in view in designing storage structures and storage godowns and also in finalizing the schedules of storage practices.

(*b*) *Oxygen availability :* The important role of oxygen in animal and plant respiration is well known. When a grain like wheat is stored in an airtight storage structure, the oxygen-content of the air in this enclosed microcosm goes on getting reduced as it is consumed in respiration both by grain and by the insects, if any, infesting the grain. Weight for weight, the oxygen consumption by insects is 130,00 times the consumption in grain respiration. Hence the reduction in oxyzen-content is much quicker if the grain is infested by insects. And, as each insect species requires a particular

TABLE 2

Oxygen-content of air in an enclosed environment with wheat grain at which the different stages of storage pests were found to be dead.

Sl. No.	*Insect Species*	*Stage*	*Oxygen Content*
1.	*Tribolium castaneum*	Full-grown larvae	6.37%
2.	—do—	Adults	7.24%
3.	*Trogoderma granarium*	Eggs	16.77%
4.	—do—	First instar larvae	5.35%
5.	—do—	Full-grown larvae	1.08%
6.	—do—	Adults	3.39%

Source : 1 and 2 (Sinha, B.P. 1965—unpublished M.Sc. thesis of IARI)
3 to 6 (Girish G.K. 1964—unpublished Ph.D. thesis of IARI)

minimum concentration of oxyzen, it is killed once the oxygen-content goes below that minimum. The minimum concentration of oxygen required by the different stages of two species of storage pests has been determined at the IARI by keeping these stages confined along with their food in airtight containers and analysing the oxygen content at the time when all the individuals are dead. The data thus collected are given in Table No. 2. It will be seen from this table, that different stages of even the same species can stand different amounts of reduction in the oxygen content. It is obvious

that further multiplication of a particular species will stop as soon as the oxygen-content goes below the level required by the most susceptible stage and not the one required by the most resistant stage. Thus, for example, the Khapra eggs lose their viability at 16.8 per cent oxyzen-content, while full-grown larvae can stand up to about 1 per cent. Naturally this pest cannot multiply when the oxygen content goes below 16.8 per cent.

Another important point brought out from these data is that the insects generally die much before the oxygen gets completely exhausted and before the question of real anaerobic respiration by the grain or the micro-organisms can be expected to arise although some micro-aerophilic bacteria grow in reduced oxygen tension. It is also clear from these data that complete airtightness is not needed. It will be enough if the storage structure is sufficiently airtight so as to bring down the oxygen-content of the enclosed air to the desired levels, as shown in Table 2. Further, it will be seen that the Khapra pest, which can thrive even at much lower moisture content, is very susceptible to the reduction in oxygen-content. Hence, if the grain is dried up to about 8 per cent moisture content and then kept in a reasonably airtight enclosure, most of the species will not multiply due to the shortage of moisture and those that will multiply for sometime will get annihilated due to the shortage of oxygen. The time taken for the reduction of oxygen to the lethal level will depend on the extent of infestation, the volume of empty space in the storage structure etc. For example, if the empty space is more, the amount of available oxygen will also be more and more time will be needed to reduce the oxygen-content to the lethal level. This explains why sometimes insects can remain alive in practically empty structures for quite long periods even if they are airtight.

(*c*) *Temperature complications* : Temperature is the most important factor controlling the development and multiplication of insects in general. Besides this simple and universal temperature effect, there are a number of harmful side complications arising out of improper or ineffective manipulation of the temperature factor. These are mainly due to (*a*) heat spots developing within the stored grain, and (*b*) development of temperature gradient generally from the middle towards the periphery. The development of the heat

spot is due to the excessive heat produced either by insect multiplication or by microbial infection in some localized pocket. Insect respiration produces both water and heat and due to comparative non-conductivity of the grain, heat dissipation does not take place effectively. The result is that both temperature and moisture increase, leading to greater multiplication, first of insects and later of micro-organisms. Sometimes these heat spots can develop even without insect infestation in case the moisture-content of the grain happens to be high enough for microbial activity. Also sometimes this chain activity goes on to such an extent that the heat developed in pockets of infestation kills the insects there but this self-sterilization of the grain is not of much help because by the time this stage is reached, the grain becomes very much damaged and spoiled. Lumps of grain are formed which give off offensive smell. The process is commonly known as 'caking'. Hence all efforts have to be directed towards the prevention of such heat spots and to cool them down in case some heating has started in some pockets. This can be done by various means, such as forced aeration, turning the grain, control of infestation by fumigation, etc. The development of the temperature gradient is due to unequal heating in the different portions of the stored grain. Generally, it is from the middle where the temperature rises due to the respiratory activities of grain, insect infestation, microbial infection, etc. to the periphery where the temperature may be low particularly if the wall of the storage structure is made of some good conductor (say metal) which dissipates that heat outside.

Also if a metallic storage structure like a big silo happens to be under direct sun, the surface facing from south-east to south-west may get comparatively more heated and a temperature-gradient may develop from south to north inside the grain. The main harm done by these temperature-gradients is in what is sometimes known as sweating of the grain. The moisture evaporating from the grain in the warmer region migrates to the cooler region and condenses there. This leads to the increase in the moisture-content in the cooler region sometimes even to the extent of the grain getting wet; the damp grain then provides better environment for the multiplication of insect infestation and microbial infection, for increased grain respiration and even for caking of the grain. Thus, it will be

seen from the above, that the grain suffers both from a poor conductivity of its own and from the good conductivity of its container. It is, therefore, advisable to make the wall of the storage structure from a material with poor conductivity and also on the other hand to make suitable arrangements to overcome the harm due to the poor conductivity of the grain itself.

Keeping in view the few basic principles enunciated above, it should become fairly easy to come to rational decisions regarding various disputed points about storage structure, storage godown and storage practices. The main points for which it is necessary to have quite clear-cut ideas are being discussed below.

Airtight versus Ventilated Storage

It has been demonstrated again and again that insects do not multiply long under airtight storage. However, as grain is also a living material, it cannot be theoretically kept indefinitely under completely airtight conditions because ultimately the oxygen is bound to get considerably exhausted and thereafter the grain will also die and deteriorate. Under practical conditions, however, it has been observed that insects die long before oxygen gets completely exhausted and thereafter the grain which consumes very little oxygen can remain healthy for quite long periods, provided its moisture content is not high, i.e. above 10 per cent or so under Indian conditions. Also in the case of airtight storage, there is no fear of increase in moisture-content from outside sources. The one disadvantage of this type of storage is that it is comparatively difficult to maintain the airtight conditions. Ventilated storage on the other hand provides a very good environment both for insects and the grain. But on the whole, insects multiply quickly and damage the grain very much unless special disinfestation operations are resorted to. Despite this distinct disadvantage, some specialists on pest control have expressed opinion in favour of ventilated storage. Obviously when the storage conditions are such that the airtightness is not enough to keep the pest infestation down, then it is certainly better that the storage be kept thoroughly ventilated. Under such circumstances, the advantage of full ventilation is that the storage conditions remain more hygienic for the workers and the chances of the deve-

lopment of heat spots remain somewhat reduced. However, on the whole the above analysis of the pros and cons of ventilated and airtight storage leads to the conclusion that whenever possible and practicable airtight storage should be preferred to ventilated storage and all planned efforts should be made in that direction.

Bag Storage versus Bulk Storage

Bag storage is largely in vogue, particularly in the Government and trade godowns, mainly because of the ease in handling and transport; otherwise there are quite strong scientific considerations in favour of bulk storage which is in vogue both at the level of cultivators who construct various kinds of storage structures like *bukhari*, *kothar* , *morai* etc. and also at the level of very advanced storage organizations making big silos and underground pits. The points in favour of bag storage are : (*a*) that each bag constitutes a definite unit which as such can be brought in, sent out, purchased or sold, (*b*) that under present Indian conditions it is easier to load and unload grain packed in bags, (*c*) that bags can be neatly arranged in stocks of different sizes, (*d*) that if any individual bag is noticed to be infested it can be easily segregated and treated, (*e*) that the surface of the bag being practically exposed to atmosphere the problem of sweating is less etc. On the other hand, the main scientific considerations in favour of bulk storage are : (*a*) that the peripheral exposed surface area per unit weight of grain is much less in the case of bulk storage and consequently the damage from external sources is reduced, and (*b*) that because of the slow movement of air in the intergranular space the conditions in the deeper layers of the grain stored in large bulk are nearer to those of airtight storage and that results in the consequent reduction in infestation which tends to remain confined to the periphery. These two main considerations in favour of bulk storage are on the whole much more weighty than several of the smaller considerations in favour of bag storage, particularly if adequate precautions have been taken against sweating of grain in bulk storage.

Underground Storage versus Above-Ground Storage

There is no intrinsic scientific difference between underground and

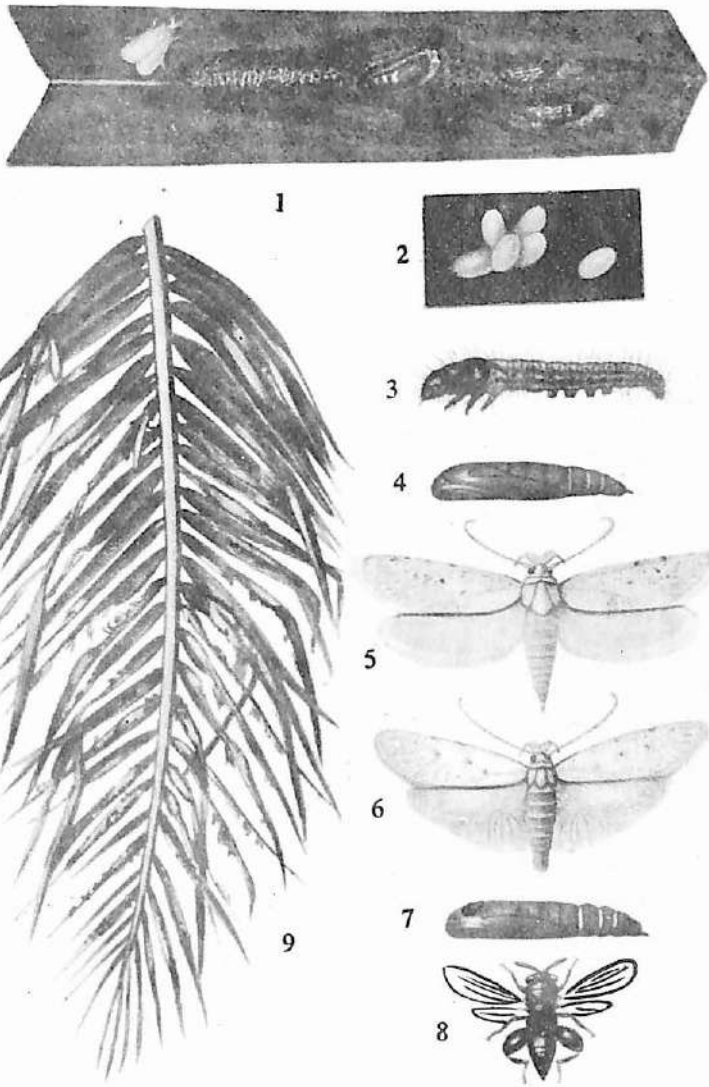


Plate XLIII—COCONUT CATERPILLAR

(*Nephantis serinopa*)

1. Leaflet showing galleries of caterpillar 2. Eggs
3. Caterpillar 4. Pupa 5. Female moth 6. Male moth
7. Parasitized pupa 8. Parasite 9. An attacked frond.

(*Proc. 5th Ent. Meeting*, p. 92)

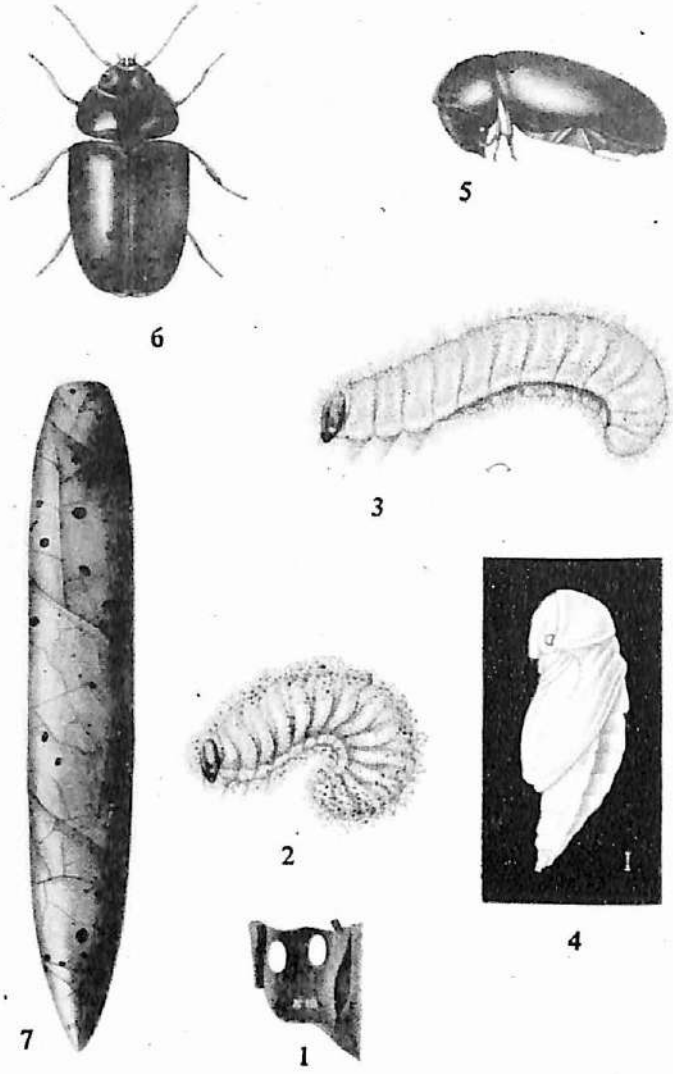


Plate XLIV—CIGARETTE BEETLE

1. Two eggs on piece of tobacco leaf 2. Larva as it is usually covered with particles of leaf 3. Larva divested of covering 4. Pupa 5. Imago, lateral view 6. Imago in resting attitude 7. Bored cheroot.

(*Indian Insect Life*, p. 318)

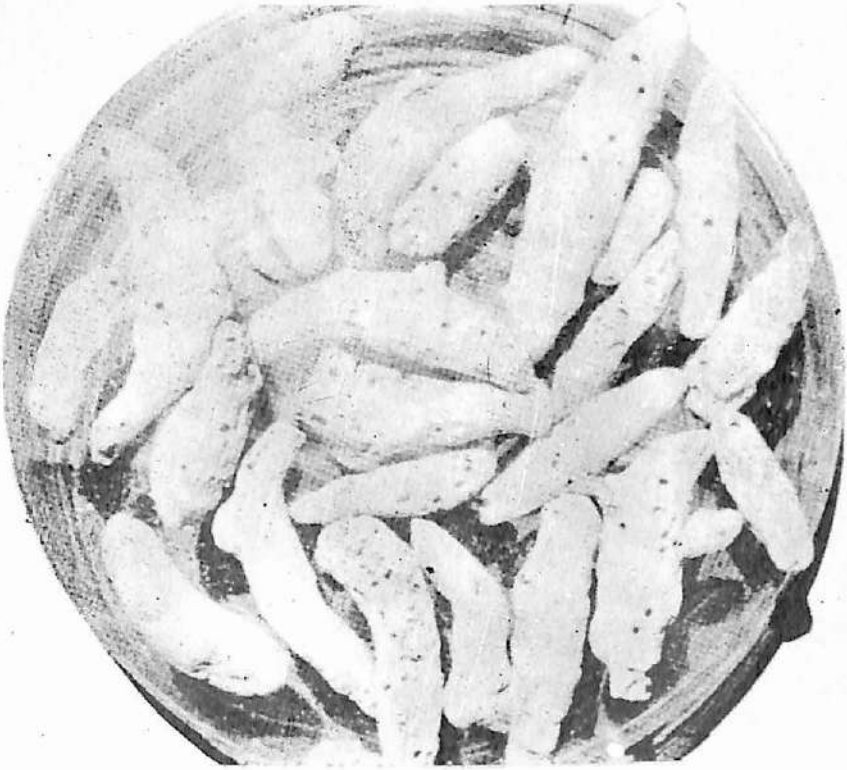


Plate XLV

Turmeric damaged by *Lasioderma serricorne* (F.)

(Courtesy: Late Dr. P. B. Mookherjee Entomologist I.A.R.I., New Delhi.)

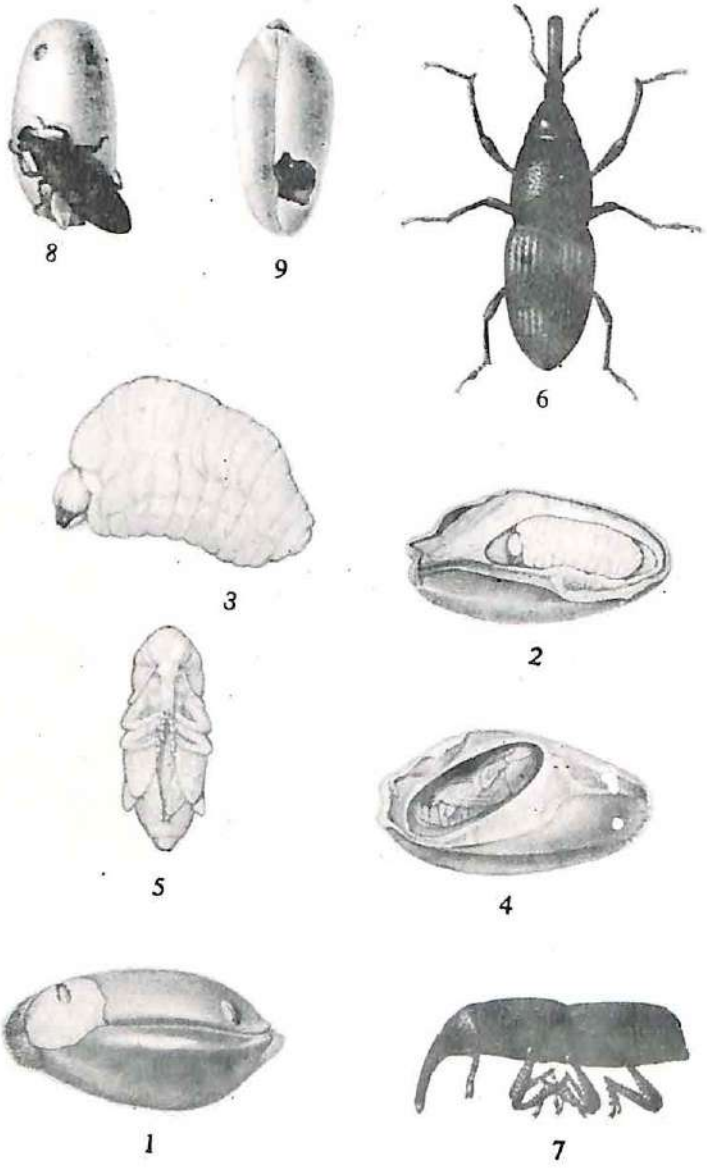


Plate XLVI—Rice Weevil

1. Eggs laid on and in a wheat grain 2 Larva feeding inside a grain 3. Larva removed from grain 4. Pupa in natural position inside grain 5. Pupa removed from grain, ventral view 6. Adult weevil from above 7. Adult weevil from side 8. Weevil gnawing into a wheat grain 9. Weevil inside a wheat grain.

(*Proc. 3rd Ent. Meeting*, p. 715)

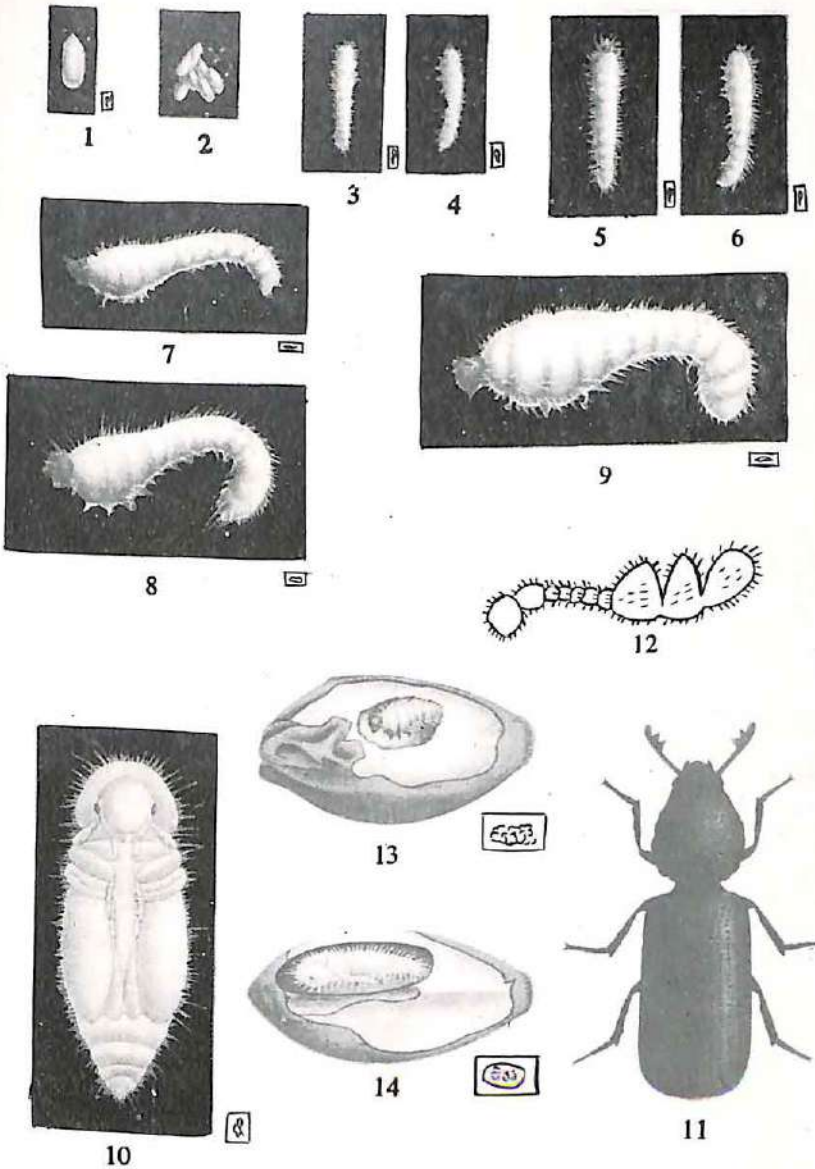


Plate XLVII—RHIZOPERHA

1. Egg 2. Cluster of eggs 3. Freshly emerged larva, dorsal view 4. Freshly emerged larva, lateral view 5. Larva after first moult, dorsal view 7. Larva after first moult, lateral view 7. Larva after second moult 8. Larva after third moult 9. Fully developed larva just before pupating 10. Pupa, ventral view 11. Adult showing the attitude when actively moving about 12. Antenna 13. Grain showing larva inside 14. Grain showing pupa in cavity excavated by larva.

(*Proc. 3rd Ent. Meeting*, p. 716)

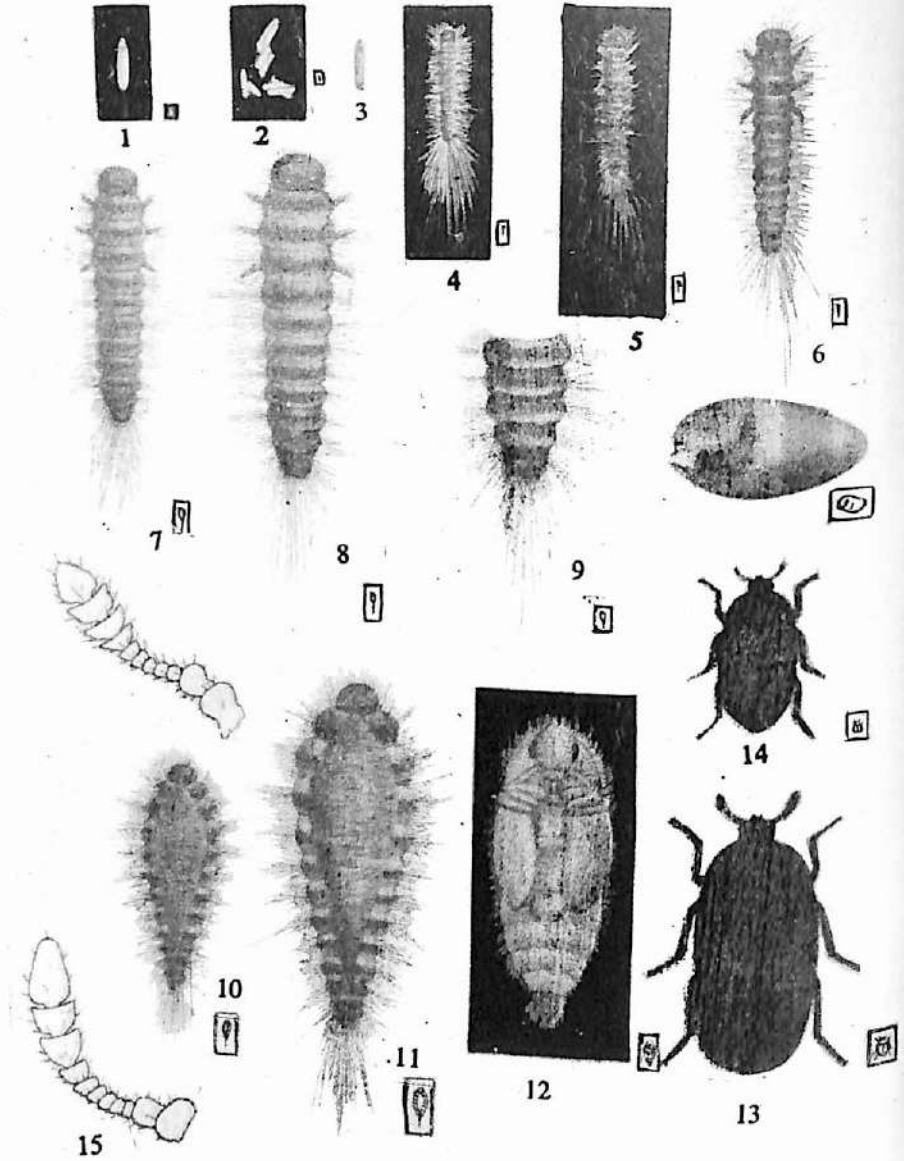
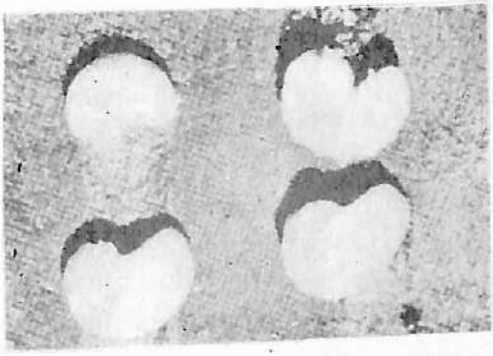


Plate XLVIII—KHAPRA BEETLE

1. Egg 2. Groups of eggs laid together 3. Egg a few days old showing signs of developing larva inside 4. Freshly-emerged larva 5. Larva after first moult 6. Larva after second moult 7. Larva after third moult 8. Larva after fourth moult 9. Posterior segments of larva after fifth moult 10. Pupa of a male beetle still enclosed in larval skin, dorsal view 11. Pupa of a female beetle 12. Female pupa removed from larval skin, ventral view 13. Female 14. Male 15. Antenna of male beetle 16. Antenna of female beetle 17. Larva feeding on a wheat grain.

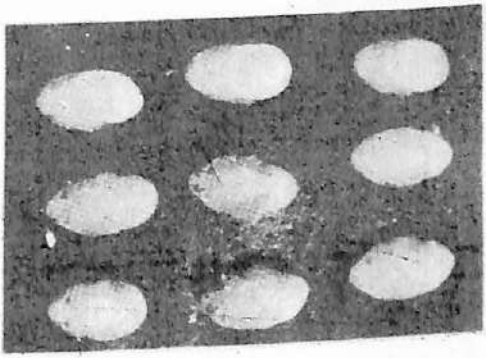
(*Proc. 3rd Ent. Meeting*, p. 717)

Adults



Larvae

Egg shells on damaged cowpea seed

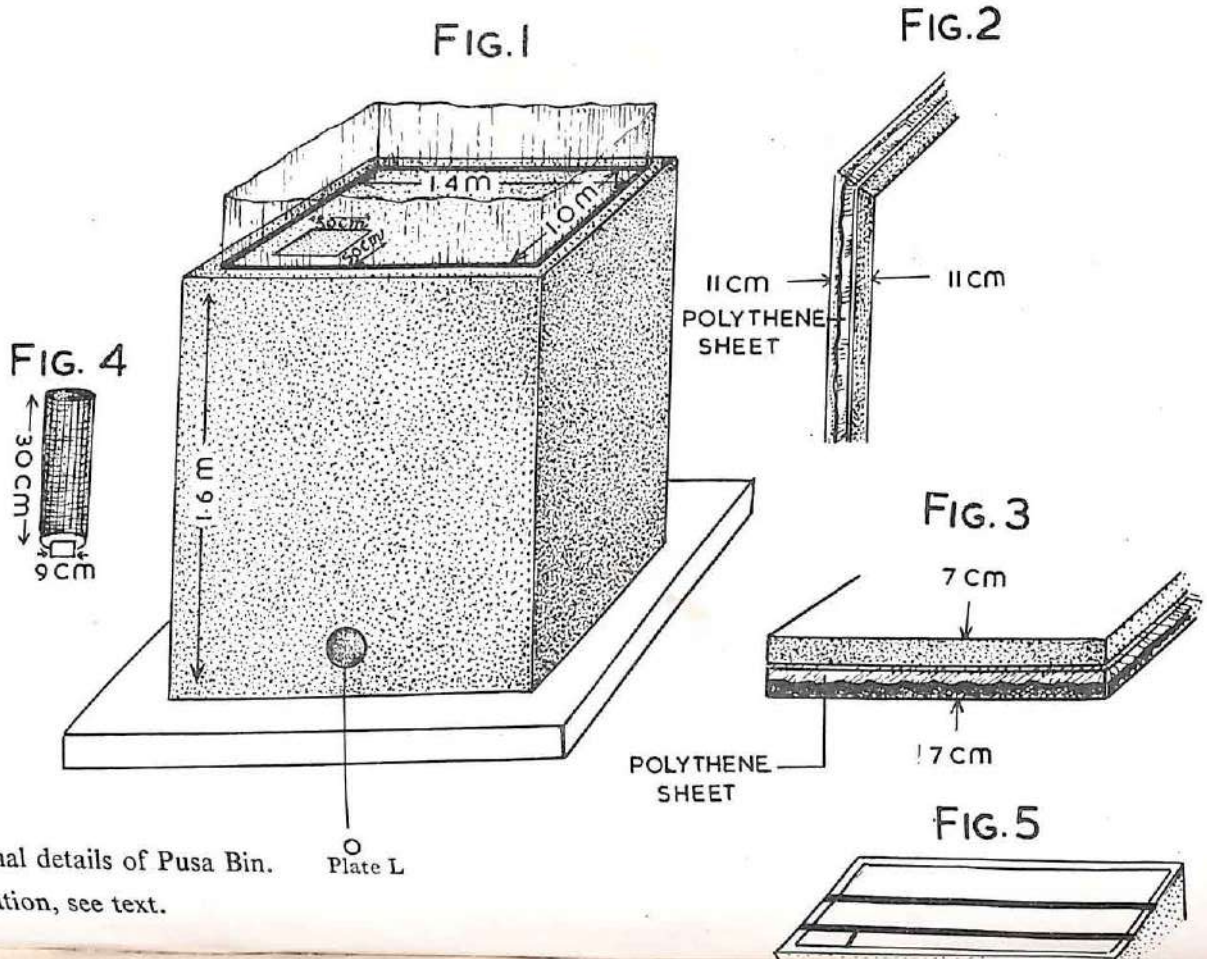


Pupae

Plate XLIX

Different stages of *Callosobruchus maculatus* Fab.

(Courtesy late Dr. P.B. Mookherjee, Entomologist, I.A.R.I., New Delhi.)



Constructional details of Pusa Bin. Plate L

For explanation, see text.

above-ground storage provided the basic requirements of safe storage enunciated earlier have been provided for. However, there are certain practical advantages and disadvantages of these two storage practices as they are generally in vogue in the country at present. These practical considerations in favour of underground storage are: (*a*) that the grain in underground storage is more free from the seasonal vicissitudes of temperature and humidity provided of course adequate precautions have been taken against seepage etc. in the underground pits particularly in regions where the water table is likely to rise; this is very desirable if the grain has been brought to the proper condition of moisture and temperature before storage, (*b*) that the underground storage pits are nearer to airtight storage with its consequent advantages mentioned earlier, (*c*) that in underground storage the grain is generally stored in bulk which has its own advantages, and (*d*) that underground storage is safer from various external sources of damage including theft. etc. The considerations in favour of above-ground storage on the other hand are : (*a*) that the above-ground storage can be maintained in more hygienic conditions (*b*) that above-ground storage is more convenient for inspection and for operations like turning the grain, and (*c*) that the danger of the grain heating up due to internal sources is somewhat less.

There has not been much controversy about other aspects like dunnage etc. It should, however, be kept in mind that there is no point in making temporary dunnage in a permanent storage godown, as is generally found to be the case. It is better to provide permanent dunnage so as to avoid annual recurring expenditure.

Storage for Different Periods

The period for which the storage is to be arranged is of vital importance in deciding about various storage practices. On the basis of this criterion, storage can be classified into the following categories :

A. *Transit storage*: In this category comes shortest-term storage in which case the grain is practically on the move or where some kind of rotation is practised so that the old stock moves out as the fresh stock comes in. The examples are many of the Government godowns, godowns at the seaports, godowns of retailers and also of some

wholesalers. In such cases, when the grain is handled at very short intervals, bag storage has to be preferred for the ease of handling and transportation; this has to be preferred till such time as modern means of handling and distribution are provided for in this country.

B. *Short-term storage* : In this category we may include such storage as is practised by cultivators who generally like to store their seed grain from harvest to sowing and foodgrain from harvest to harvest, if not for longer periods. The storage in the Warehousing Corporation may also be included in this category. These people generally and rightly use various types of storage structures like *bukhari*, *kothar*, *morai* etc. which are all examples of non-airtight bulk storage. The necessity of bringing about the desired improvements in these structures has been realized for sometime past and the Indian Standards Institution has formulated standards for these different types. The Indian Agricultural Research Institute has, on the other hand, devised what is called Pusa Bin for such storage and this combines in itself the various ideal storage requirements mentioned earlier.

C. *Long-term storage* : In this category comes the storage for such long periods as required by (*i*) large-scale trade stockists, and (*ii*) Government agencies desiring to keep buffer stocks or to maintain food banks.

It is for such long-term storage that we must make very carefully thought-out planning and recommendations.

Recommendations

1. *Grain dryers* : As mentioned earlier, the moisture-content of the grain is the most vital factor to be taken care of in order to ensure safe storage of the grain. In dry months and in dry areas, the grain can be dried directly in the sun but the same is not possible in wet areas and in wet months even in dry areas. Hence it is highly advisable that a suitable grain dryer is provided for each storage godown without exception. This should be considered as an item of highest priority for any storage organization.

2. *Storage structures and godowns* : These have to be somewhat different for short-term, long-term and transit storages.

(*a*) *Short-term rural storage* : For this purpose an ideal storage

structure has been devised by the I.A.R.I. It is called the Pusa Bin. The rationale of the structural design of this bin is as follows :

Earthern structures of various shapes and sizes provide the easiest and most economic methods for the storage of grains under rural conditions in many parts of our country. However, in this method of storage, one often finds the grains infested with insects. In some localities rats also pose a serious problem in this kind of storage, since they easily cut through the mud walls and do considerable damage to the grains stored inside the mud structure. In some wet regions of the country, grains are also found to be affected by the high humidity conditions prevailing outside and leading to a process which ultimately results in the caking of the grains. As a result of all these troubles, the loss of foodgrains in storage is often quite considerable. With a view to reducing these losses, a thin sheet of polythene film (0.17 to 0.18 mm thick) is embedded in the mud wall of an ordinary earthen structure. The idea behind the sandwiching of the polythene film within the body of the wall is to combine the mechanical strength of the mud wall with the just effective imperviousness of polythene films to vapours and gases. The polythene film being fairly impervious to water vapours does not allow the atmospheric moisture to enter the grains. Also this film is impervious enough to oxygen with the result that the oxygen tension within the structure is reduced to such an extent that insect multiplication becomes impossible. On the other hand, the earthen layers both inside and outside the polythene film keep the film safe from mechanical injuries due to abrasion and handling stress and strain. When a polythene film is used as an inner or outer lining instead of being embedded within the wall, it gets damaged quickly and becomes ineffective. Also earthen layers provide very good walls for the storage structures because they have poor thermal conductivity and reduce the dangers of sweating at the periphery. Thus it will be seen that the Pusa Bin combines in itself all three major requirements of safe storage, viz. (i) it is moisture-proof, (ii) it is just sufficiently airtight, and (iii) its walls have poor thermal conductivity. The earthen layers can be replaced by any other material of poor thermal conductivity ; 4 of course, wood has the danger of being attacked by termites.

Results of comparative tests have shown that freshly-harvested and dried wheat could be kept safe for a long time in this improved type of storage structure. It has also been shown that none of the four principal storage pests, viz. *Sitophilus oryzae*, *Rhizopertha dominica*, *Trogoderma granarium* and *Tribolium castaneum*, could breed well in this improved type of storage structure (even when they were introduced), provided the initial moisture-content of wheat was at a level of 10 per cent or below. The viability of the wheat seeds is also not affected when stored in this type of structure for more than three years. There is no obvious factor which is likely to limit the size of the storage structure. However, the details of the constructional procedure and the cost involved in making a structure of about 2,000 kg. are given below :

Details of construction of the Pusa Bin

(*Plate L*)

Shape :	Rectangular.
Capacity :	1.7 tonnes (approx.)
Size :	1.40 metres long × 1.00 metre broad × 1.60 metres high (internal dimensions) (Fig. 1)
Four walls :	These consist of two layers of mud (or unburnt bricks) with a polythene film sandwiched in between. Each layer of mud or bricks is about 11 cm thick (Fig. 2).
Floor and roof :	These consist of two layers of mud with a polythene film sandwiched in between. Each layer of the roof is 5 cm thick, while each layer of floor is 7 cm thick. (Fig. 3).
Manhole	50 cm × 50 cm in one corner of the top surface.
Quantity of polythene film :	8.5 metres (700 gauge) (180 cm width).
Cost of polythene film :	Rs. 60.00 approx.
No. of bricks (*kutcha*) required :	1,150 (brick-size 22 cm long × 11 cm broad × 7 cm thick).

No. of bricks (burnt) required : 160

Outlet : An ordinary pipe made of galvanized tin sheet of 9 cm diameter and 30 cm in length with a tight-fitting lid (Fig 4).

Wooden frame : Used on the top of the structure for supporting the roof (Fig. 5).

The structure is constructed over a *pucca* brick floor. If a *pucca* brick floor is not available, it should be made at a suitable site. Next, a mud platform of roughly 1.7 m × 1.2 m × 7 cm (thick) size is made and a polythene film of 1.8 m × 1.4 m size is placed over it. A 7 cm thick layer of mud is then applied over the film covering the same size as the platform under the polythene film. The inner wall (11 cm thick) of the structure covering the four sides is then constructed. The inner layer of the mud roof of the structure is then made by using 5 cm-thick mud slabs prepared earlier and placing them over a wooden frame (frame shown in Fig. 5). An area of 50 cm × 50 cm size is, however, kept open in one corner to serve as a manhole. The entire structure is then covered with the polythene film carefully, the polythene cover having been prepared earlier by the method of heat-sealing; thereafter, the free edges of the polythene sheet near the base are also similarly sealed. At this stage, the outlet mentioned earlier is fixed by making a hole in the inner mud layer as well as the polythene film. Finally, the outer layer of the walls of 11 cm thickness are created all round the structure covering the polythene film. A 5 cm-thick mud plaster is also put over the polythene film at the top, leaving out the manhole. The portion of the polythene film covering the manhole is then cut diagonally for making the necessary passage. When the structure is filled with grain, the manhole is finally sealed with a square piece of polythene film. Normally, grains are to be taken out as and when necessary through an outlet fixed near the base of the structure..except that at the end of the storage season, the manhole at the top can also be used for this purpose. For making the structure rat-proof, the outer wall of the structure may be constructed using *pucca* (burnt) bricks upto a height of 45 cm. Alternately, a tin-band (from old kerosene tins) may be provided

round the structure upto the same height. By this way the structure is protected from damage by rats.

(*b*) *Long-term storage* : Airtight bulk storage is best suited if the stock has to be maintained really on a long-term basis. It is generally in the form of modern silos above ground or as airtight moisture-proof underground pits. Of course, there are often storage arrangements which are far from satisfactory. Large-sized structures constructed on the basis of the Pusa Bin will also serve well for long-term storage. Of course, these structures have to be located under fairly rainproof conditions. Where fresh arrangements for long-term storage are under consideration, the best course will be to provide both for a good storage godown and for a good storage structure in this godown. The godowns should have adequate provision for making the whole godown sufficiently airtight for fumigation with poisonous gases and also for proper aeration after fumigation. This can be easily managed by having ventilators fitted with both proper exhaust fans and also a suitable arrangement for closing the ventilator airtight. The doors should also be suitable for this purpose. Then inside the godown there should also be a permanent structure for airtight bulk storage. The structure based on the principle of the Pusa Bin will be best suited for such godowns. If these permanent provisions are made from the very beginning, the cost of storage is bound to be quite cheap in the long run. If both the godown and the storage structures are properly made, there may be no necessity for taking any chemical control measures. If, however, some infestation somehow creeps in, one can disinfest either the individual storage structure or the whole godown as such.

(*c*) *Transit storage* : In the past, transit storage has been maintained in a variety of sheds available on emergency basis instead of proper storage godowns. In these sheds, generally bagged storage has been practised, the bags being arranged in stacks. For future, the best course will be to have proper godowns as suggested in the previous paragraph. In these godowns, there should be permanent cubicles in which the bagged grain can be suitably stacked. The cubicles should be such as can be made airtight both for storage and for fumigation, if need be. This will mean a proper combination of airtight storage and bag storage. This combination will

provide both ideal storage conditions and all handling facilities of bag storage specially needed for transit storage. The structure based on the principle of the Pusa Bin will do very well for this purpose also.

Chemical Control Operations

If the recommendations given above for safe storage are properly followed and provided for, there should be no necessity to use insecticides in grain storage. If, however, it has to be done, the following points may be kept in view :

(*a*) *Mixing of insecticides* : It has been shown beyond doubt that persistent insecticides mixed with grains can keep the grain safe from insect infestation for varying and quite long periods. Although this provides quite a potent method for storing grain meant solely for seed purposes, a recommendation to this effect cannot be free from serious hazards particularly because the grain though originally meant solely for seed can always find its way to the food market. Also if the general public becomes well conversant with this method, it will become quite difficult to check the unscrupulous people from applying the same method to foodgrain. Hence it is advisable to desist from this otherwise tempting recommendation.

(*b*) *Impregnation of bags with insecticides* : This recommendation is also quite tempting and has been made by a number of workers but there is a subtle limitation due to which this method generally does not work. The storage pests, particularly the beetles, take just a few minutes to enter the weave of the bag unless it is very close and tight and during this short period, they generally do not pick up the lethal dose. Due to this limitation, this method cannot be much depended upon.

(*c*) *Dusting of the bags* : This is likely to be more effective than impregnation because in this case the dust can stick to the insect body and some of it may be carried along with the insect. Of course, this may also lead to greater contamination than impregnation. The safest dust to be used for this purpose is the one based on pyrethrum as an active ingredient fortified by a suitable synergist. However, this insecticide is not of persistent type and

breaks down within a very short time

(*d*) *Fumigation and fumigants* : This is the best and most dependable technique for disinfesting grain. One has, however, to be careful about the choice of the proper fumigant. In this connection it may be mentioned that a fumigant like carbon tetrachloride is comparatively less toxic to insects but its good point is that it is less absorbed by the grain. Another fumigant like ethylene dibromide is comparatively highly toxic to the insects, but its bad point is that it is highly absorbed by the grain. Other fumigants like ethylene dichloride occupy an intermediate position in both respects. Hence great care has to be taken in the choice of a fumigant. An ethylene dichloride-carbon tetrachloride mixture in the 3:1 ratio has been much in vogue because of its comparative safety to operators. Methyl bromide is a very good general-purpose fumigant but it has to be handled with utmost care and with special fumigation appliances. During recent years, phostoxin has become quite popular, but due to the extremely hazardous nature of phosphine gas, generated by the tablets, its use by untrained individuals has not been recommended.

(*e*) *Disinfestation of godowns* : Fumigation is the best technique for disinfesting godowns, provided the godowns are structurally fit for this operation. Otherwise a good spray of the walls with a suitable persistent insecticide can be resorted to. The safest spray is the one based on pyrethrums fortified by a suitable synergist. At present malathion, which is also a relatively safe insecticide, is used widely for this purpose.

APPENDIX

SOME INSECTICIDES RECOMMENDED FOR THE CONTROL OF MAJOR CROP PESTS

Common name of pest	*Scientific name*	*Recommended chemical control*
1. Polyphagous pests		
(i) Red hairy caterpillar	*Amsacta moorei* Butler	Dust 0% BHC, the early stage is easy to control.
	A. albistriga Walker	Do not use this insecticide if the infestation is on cucurbits or root crops.
(ii) Padhka grasshopper	*Hieroglyphus banian* Fabricius	Dust 5-10% BHC, depending on the stage of hoppers.
	H. nigrorepletus Bolivar	
2. Pests of paddy		
(i) The stem borer	*Tryporyza incertulas* Walker	Give three fortnightly sprayings with 0.04% diazinon, phosphamidon, fenitrothion, dimethoate, enaosulfan, or two applications of carbofuran (3%), phorate (10%), lindane (2%) or endoslfan (4%) granules, 2 and 6 weeks after transplating.
(ii) Swarming caterpillar	*Spodoptera mauritia* Boisduval	Dust 10% BHC or spray 0.04 endosulfan or 0.2% carbaryl.
(iii) Gundhi bug	*Leptocorisa acuta* (Thnb.)	Dust 10% BHC or carbaryl at the time of flowering.
(iv) Paddy gall fly	*Orseolia oryzae* Wood-Mason	Spray 0.03% phosphamidon or dimethoate, 4 times during the vegeative phase of the crop.

Common name of pest	Scientific name	Recommended chemical control
3. Pests of wheat and barley		
(i) Termites	*Odontotermes obesus* Rambur	Mix thoroughly 5% aldrin or chlordane dust with the soil just at the time of sowing or during preparation of the land for sowing.
(ii) Gujhia weevil	*Tanymecus indicus* Faust	Mix thoroughly 5% aldrin or heptachlor dust upto 12.25 cm deep layer of soil, for adults dust 5% BHC.
4. Pests of maize and millets		
(i) Maize stem borer	*Chilo partellus* (*zonellus*) (Swinhoe)	Apply 4% endosulfan or carbaryl granules or spray 0.05% lindane or endosulfan or 0.2 per cent carbaryl. Leaf whorls should be properly covered.
(ii) Shootfly	*Atherigona soccata* (Rondani)	Treat the seed material with carbofuran (20 : 1) or apply 3% carbofuran or 5% disulfoton or 10% phorate granules.
(iii) Earhead bug	*Calocoris angustatus* Lethierry	Dust the maturing earheads with 5% BHC or 4% carbaryl or spray 0.1% carbaryl (W.P.).
5 Pests of sugarcane		
(i) Top borer	*Tryporyza nivella* Fabricius	Apply 4% carbaryl or endosulfan granules in leaf whorls or spray 0.05% monocrotophos.
(ii) Stem borer	*Chilo infuscatellus* Snellen	—
(iii) Root borer	*Emmalocera depressella* Swinhoe	—
(iv) Pyrilla leafhopper	*Pyrilla perpusilla* Walker	Dust 5% BHC or spray 0.03% monocrotophos, dimethoate, phosphamidon or methyl demeton. Special care should be taken to cover the undersurface of the leaves.

Common name af pest	Scientific name	Recommended chemical control
6. Pests of pulse crops		
(i) Gram pod borer	*Heliothis armigera* Hübner	Dust 4% carbaryl or spray 0.05% endosulfan or 0.04% monocrotophos.
(ii) Cut worms	*Agrotis ipsilon* Hufnagel	Rake into soil 5% aldrin, heptachlor or chlordane and dust the crop with 10% BHC.
	Ochropleura flammatra Devis & Schiffer-Mueiller	
	A. segetum Schiffer Dems Mueiller	
	A. spinifere Hübner	
(iii) Plume moth caterpillar	*Exelastis atomosa* Walsingham	Dust with 5% carbaryl or endosulfan, or spray with 0.04% monocrotophos or 0.05% endosulfan.
(iv) Pea leafminer	*Phytomyza atricornis* Meigen	Spray 0.05% dichlorovos (DDVP), 0.1% lindane or carbaryl twice.
(v) Cowpea stemfly	*Melanogromyza phaseoli* Coquillett	Dust 5% carbaryl, 5% endosulfan or spray 0.05% monocrotophos or dimethoate when the maggots are inside the leaves.
(vi) Red gram pod fly	*Agromyza obtusa* Pallas	The same as for cowpea stem fly.
(vii) Aphids	*Aphis cracciovra* Koch	Apply phorate 10G or disulfoton 5G granules 1.5 kg a.i. ha at the time of sowing or dust 5% BHC or spray twice 0.03% monocrotophos, phosphamidon, dimethoate or methyl-deme ton. Granular application though costly, can control a number of other pests also.

Common name of pest	Scientific name	Recommended chemical control
7. Pests of oilseed crops		
I. Pests of mustard crop		
(*i*) Mustard aphid	*Lipaphis erysimi* Kaltenbach	Spray 0.05% lindane or 0.02% phosphamidon or 0.03% monocrotophos or methyl demeton or dimethoate.
(*ii*) Mustard sawfly	*Athalia lugens proxima* (Klug)	Dust 5% BHC, do not consume the dusted leaves as vegetable.
II. Pests of groundnut		
(*i*) Groundnut leaf miner	*Stomopteyx nerteria Meyrick*	Dust 5% BHC or carbaryl.
(*ii*) Groundnut stem borer	*Sphenoptera perotettig* uerin	Rake into soil 5% aldrin or chlordane dust.
III. Pests of Sessamum		
(*i*) Leaf and pod caterpillar	*Antigastra catalaunalis* Duponchal	Dust 10% BHC or spray 0.1% BHC + 0.1% DDT (Wettable powders).
(*ii*) Hawk moth	*Acherontia styx* Westwood	Dust 10% BHC.
IV. Pests of Castor crop		
(*i*) Castor semi-looper	*Achaea janata* Linnaeus	Dust 5% BHC or spray 0.05% endosulfan or 0.2% carbaryl.
8. Pests of vegetables		
I. Fruit flies		
(*i*) Melon fruit fly	*Dacus cucurbitae* Coquillett *D. ciliatus* Loew *D. diversus* Coquillett	Spray trees as well as hedges and other vegetation in the vicinity with 0.1% BHC+0.1% DDT. A poison bait (20 gm malathion 50% W.P. or 50 ml of diazinon + 200 gm of gur or molasses in 2 litres of water) kept in flat containers attracts and kill flies.

Common name of pest	*Scientific name*	*Recommended chemical control*
(*ii*) Ber fruitfly	*Carpomyia vesuviana* Costa	Repeatedly plough around the trees during April to June and spray tri-weekly with 0.04% dichlorvos (DDVP) or 0.05% malathion.
II. Red pumpkin beetles	*Aulacophora foveicollis* Lucas *A. intermedia* Jacoby *A. cincta* Fabricius	Rake into soil 5% aldrin against grubs, dust the foliage with 4% carbaryl or spray 0.05% malathion.
III. Brinjal borers		
(*i*) Brinjal shoot and fruit borer	*Leucinodes orbonalis* Guenee	Spray 0.03% diazinon or 0.1% lindane or 0.1% carbaryl; remove the fruits before spraying and do not harvest any fruits for 3-4 days after treatment.
(*ii*) Brinjal stem borer	*Euzophera perticella* Ragonot	Spray 0.03% diazinon or 0.1% lindane or 0.1% carbaryl; remove the fruits before spraying and do not harvest any fruits for 3-4 days after treatment.
IV. Hadda beetles (leaf eating beetles)	*Epilachna dodecastigma* Mulsant *E. vigintioctopunctus* Fabricius *E. ocellata* Redtenbacher	Spray 0.1% carbaryl or 0.05% malathion or dichlorvos (DDVP).
9. Pests of fibre crops		
I. Cotton		
(*i*) Spotted bollworms	*Earias insulana* Boisduval *E. vittella* Fabricius	Spray 0.1% carbaryl and 0.03% monocrotophos alternately at fortnightly intervals 2-3 times.
(*ii*) Pink bollworm	*Pectinophora gossypiella* Saunders	Spray as in case of spotted bollworms.

Common name of pest	Scientific name	Recommended chemical control
(*iii*) Cotton jassid	*Amrasca biguttula biguttula* Ishida	Spray the crop fortnightly with 0.02% phosphamidon, monocrotophos, methyl demeton, dichlorvos or dimethoate, starting with the appearance of the pest. 2-3 sprayings may be necessary.
(*iv*) Cotton whitefly	*Bemisia tabaci* Gaennadius	Spray the crop fortnightly with 0.02% phosphamidon, monocrotophos, methyl demeton, dichlorvos or dimethoate, starting with the appearance of the pest; 2-3 sprayings may be necessary.
II. Jute		
(*i*) Jute semi-looper	*Anomis sabulifera* Guenee	Spray 0.05% endosulfan or 0.1% carbaryl.
(*ii*) Stem girdler	*Nupserha bicolor postbrunea* Dutt	Spray 0.05% endosulfan or 0.1% carbaryl.
(*iii*) Jute stem weevil	*Apion corchori* Marshall	Spray 0.05% endosulfan or 0.1% carbaryl.
10. Pests of fruits and fruit trees		
(*i*) San jose scale	*Quadraspidiotus pernicious* Comstock	Spray 0.03% methyl demeton, diazinon, dimethoate, phosphamidon or monocrotophos.
(*ii*) Wooly aphid	*Eriosoma lanigerum* Hausmann	Spray aerial parts of the tree with 0.03% dimethoate, phosphamidon or monocrotophos during spring (March-April) and again during summer (June-July).
(*iii*) Fruit sucking moths	*Otheris fullonia* (Clerck) *O. materna* (Linnaeus) *Achaea janata* Linnaeus *Calpe emarginata* Fabricius	Poison baiting with 20 g malathion 50% W.P. or 50 ml diazinon + 200 g gur or molasses in 2 litres of water.

Common name of pest	Scientific name	Recommended chemical control
(*iv*) Citrus leaf miner	*Phyllocnistis citrella* Stainton	Spray 0.04% monocrotophos or phosphamidon.
(*v*) Lemon butterfly	*Papilio demoleus* Linnaeus *P. polytes* Linnaeus *P. machaon asiatica* Menestries	Spray 0.05% endosulfan or 0.1% carbaryl.
(*iv*) Anar butterfly	*Virachola isocrates* Fabricius	Spray with 0.05% endosulfan or 0.1% carbaryl.
(*vii*) Mango-hoppers	*Idioscopus clypealis* (Lethierry) *I. niveosparsus* (Lethierry) *I. nigroclypeatis* (Metichar) *Amritodus atkinsoni* (Lethierry)	Spray 0.03% phosphamidon, diazinon, monocrophos or methyl demeton, once before flowering (January), 1-2 times after flowering and again 2-3 times during June-July (in endemic areas).
(*ix*) Mango mealy bug	*Drosicha mangiferae* (Green)	Apply 5% aldrin dust to the soil around the base of the trees to reduce pest population. Spray 0.04% diazinon or monocrotophos to kill young bugs.
(*x*) Bark eating caterpillar	*Indarbela quadrinotata* Walker *I. tetraonis* Moore	Remove all the ribbon-like webs and treat the holes with swabs of cotton wool soaked in carbon bisulphide or chloroform or petrol or 0.1% dichlorvos (DDVP) or 0.05% trichlorofon and seal the holes with mud. Such holes as may open again may be retreated.
(*xi*) Mango stone weevil	*Sternochetus mangiferae* Fabricius *S. frigidus* Fabricius	Spray with 0.1% malathion+0.02% lindane, 2-3 times at 15 to 20 days interval after the formation of young fruits.
11. Pests of plantation crops		
I. Tea		
(*i*) Bunch caterpillar	*Andraca bipunctata* Walker	Treat with 0.05% endosulfan or 0.2% carbaryl or 0.1% lindane.

Common name of pest	Scientific name	Recommended chemical control
(*ii*) Bag worm	*Clania crameri* Westwood	Spray 0.1% malathion or 0.05% lindane.
(*iii*) Mosquito bug	*Helopeltis antonii* Signoret *H. febriculosa* Bergrath	Spray 0.1% malathion or 0.05% lindane. Spray 0.1% malathion or 0.05% lindane.
II. Coffee		
(*i*) White stem borer	*Xylotrechus quadripes* Chevrolet	Swab the main stem and thick primary branches with 0.25% BHC (W.P.) once during April-May and twice during September-January.
(*ii*) Shot hole borers	*Xylosanders compactus* Eichoff *Xyleborus conidens* Eggers	Swab the main stem and thick primary branches with 0.25% BHC (W.P.) once during April-May and twice during September-January.
III. Coconut		
(*i*) Rhinoceros beetle	*Oryctes rhinoceros* (Linnaeus)	Spray 0.1% BHC on breeding (manure) pits, fill the leaf axils with 5% BHC or chlordane dust mixed with sand (1:1)
(*ii*) Black headed caterpillar	*Nephantis serinopa* (Meyrick)	Spray 0.1% BHC+0.1% DDT or 0.05% endosulfan.
12. **Storage pests**		
(*i*) Rice weevil	*Sitophilus oryzae* Linnaeus	Fumigate under air tight conditions with ethylene-dibromide, methyl bromide or phostoxin.
(*ii*) Lesser grain borer	*Rhizopertha dominica* Fabricius	
(*iii*) Khapra beetle	*Trogoderma granarium* Everts	

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This book is meant primarily for layman and non-specialist who wishes to raise pestfree crops on his farm. With a systematic attack on these pests, the country's available production of foodgrains can certainly be increased to some extent, thereby helping to lessen its dependence on imports. Dr. Pradhan has brought his expert knowledge of insect pests of crops and of their control measures to bear on this book. He has dealt in it in detail with no less than seventy species of pests.

A fellow of the Entomological Society of London, the late Dr. S. Pradhan, M.Sc., Ph.D. (Lond.), D. Sc. (Luck.), F.E.S.I., F.N.I. was a life fellow of the Entomological Society of India and the National Institute of Sciences. Widely travelled, he contributed many research papers and review articles to periodicals in India and abroad. He was connected with several national and international pest control organisations, and was for some time Head of the Division of Entomology, Indian Agricultural Research Institute, New Delhi.

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